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BRIDGE INFRASTRUCTURE IN SECONDARY ROADS OF ANTIOQUIA

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ABSTRACT

Roads are the main tool for business and economic development of a region. Bridge failures cause interruptions in normal traffic and ground shipping of goods, producing incalculable losses while normal traffic is restored. Antioquia has one of the most extensive road networks in Colombia with a large number of bridges that make up its road infrastructure assets. Many of these bridges have not been properly maintained since their construction, which can cause structural failures and even the possibility of collapse. An inventory of all bridges in secondary roads in the Department of Antioquia identified the main physical parameters of each bridge, the building type, the structure type, and the current level of damage. The inventory showed that reinforced concrete is the most common structural type used in bridges, of lengths most commonly between 5m and 10m, of which 11% require immediate intervention due to the level of damage in their structure, while 48% of them are functioning properly.

KEYWORDS: bridges; roads; infrastructure; Department of Antioquia.

LA INFRAESTRUCTURA DE PUENTES EN LAS VÍAS SECUNDARIAS DEL DEPARTAMENTO DE ANTIOQUIA

RESUMEN

Las vías terrestres son la principal herramienta para el desarrollo comercial y económico de una región. La falla de un puente en un proyecto vial genera la interrupción total del tráfico de bienes en su superficie, produciendo cuantiosas e incalculables pérdidas mientras se restituye el normal flujo vehicular. Antioquia cuenta con una de las redes viales secundarias más extensas del territorio colombiano, y en ella hay un número importante de puentes que conforman su patrimonio vial. Gran porcentaje de estos puentes no han recibido un mantenimiento

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adecuado desde su construcción posibilitando la aparición de fallas en su estructura e incluso su eventual colapso. El inventario realizado a la totalidad de puentes de las vías secundarias del Departamento de Antioquia identificó los principales parámetros físicos del puente, su tipología constructiva, el tipo de estructura y el nivel de daños presentado. Como resultado se observa que la tipología estructural más empleada es la de puentes de concreto reforzado, con una longitud de mayor repetición entre 5m y 10m, de los cuales el 11 % requiere una intervención inmediata por el nivel de daños presentados y el 48 % de ellos se encuentran funcionando adecuadamente.

PALABRAS CLAVES: puentes; red vial; infraestructura; Departamento de Antioquia.

A INFRA-ESTRUTURA DE PONTES NAS ESTRADAS SECUNDÁRIAS DO DEPARTAMENTO DE ANTIOQUIA

RESUMO

As estradas são a principal ferramenta para negócios e desenvolvimento econômico de uma região. O fracasso de uma ponte em um projeto de estrada gera o interrupcao total do tráfego de bienes na sua superfície, produzindo grandes perdas e incalculáveis entanto que fluxo do tráfego normal é restaurado. Antioquia tem uma das maiores redes de estradas secundárias da Colômbia, e em ela há um número significativo de pontes que compõem seus ativos rodoviários. Uma grande porcentagem dessas pontes não foram devidamente mantidos desde a sua construção permitindo o aparecimento de falhas em sua estrutura e até mesmo seu possível colapso. O inventário feito na totalidade das estradas secundárias e das pontes do Departamento de Antioquia identificou os principais parâmetros físicos da ponte, seu tipo de construção, tipo de estrutura e nível de dano apresentado. O resultado mostra que o modelo estrutural mais utilizado é a ponte de betão armado com um comprimento maior sobreposição entre 5m e 10m, dos quais 11 % necessitaram de intervenção imediata pelo nível de danos produzidos e o 48 % de eles estão funcionando corretamente.

PALAVRAS-CHAVE: pontes; rede rodoviária; infra-estrutura; Departamento de Antioquia.

1. INTRODUCTION

The commercial performance of any region is directly related to the condition of its roads and road infrastructure assets. Bridges are structures that allow us to cross geographical features in order to create uninterrupted roadways and ensure efficient travel between two regions. During the heavy rainy seasons in Colombia from 2010 to 2012, several bridges collapsed, leaving many outlying populations cut off, as well as some capital cities. The Department of Antioquia was not exempt from this type of occurrence; in fact, a large proportion of its inhabitants saw tons of their products deteriorate as a consequence of the obstructions caused by the collapse of bridges and roadways, causing numerous economic losses to Antioquia's inhabitants and detrimental effects to state finances.

Likewise, the scarce maintenance and infrequent checks that are made to the structural system of a great number of bridges in Colombia increase the possibility of failures due to structural deterioration, which later leads to a partial close, and in more extreme cases to the structure's collapse.

Therefore, with the support of the *Secretaría de Infraestructura Física del Departamento de Antioquia* (Physical Infrastructure Secretariat of the Department of Antioquia), a general inventory of all the bridges in its secondary road network has been developed in order to establish a statistical tool that can be of support to different government entities in charge of the proper functioning of this type of structure. This information will allow them to understand the current condition of their infrastructure and implement preventive and corrective maintenance plans to mitigate the main problems these structures currently have, and to generate a policy of periodic inspection in order to conserve this type of infrastructure in proper conditions in the Department of Antioquia.

This study, carried out between 2008 and 2012, is a complete inventory of all the bridges in the secondary road network in the Department of Antioquia. This article presents a statistical analysis of the different typologies of the 1,283 bridges assessed in the network.

2. THEORETICAL FRAMEWORK

From the beginnings of human history, man has needed to cross obstacles such as rivers, ravines, and other topographical features. To do so, he saw the challenge of building the first bridges with the help of materials such as wood, stone, guadua (bamboo), liana, and other materials. This type of structure is considered to be one of the most ancient construction activities carried out by humans. From bridges built with stone, bricks, and mortar in the Roman civilization, followed by rope suspended bridges of the Inca civilization, through the year 1840, when wide and rapid development of bridge construction took place in the world with the industrialization of steel, bridges have been of great historical importance in the development of different human civilizations, both in terms of their economic performance and their social growth (Chinchilla et al., 2008).

In the Department of Antioquia, structures like the Puente de Occidente (**Figure 1**) have been historical, cultural, and commercial landmarks for the development of the department and the country, evidencing the importance of this type of structure for the progress of a region (Londoño, 2008).

Figure 1. Puente de Occidente, Antioquia, Colombia.

Highways slowly began to be configured in Antioquia between 1915 and 1920. With them arose the growing necessity of building bridges to communicate these roadways. By the year 1935, there were nearly 915 kilometers of highways in Antioquia, the majority of them from the city of Medellin to different regions in the department (Gómez, 1991). Although these first highways made up isolated stretches, they were generally intended to reach a train station, given that this was the central backbone of transportation in the region during that period (Gómez, 1991).

The road network in the Department of Antioquia is made up of 20,116 km, of which 1,515 km (7.5%) belong to the primary road network, 4,822 km (24.0%) make up the secondary road network, and 13,779 km (68.5%) belong to the tertiary road network (Secretaría de Infraestructura de Antioquia, 2011). Similarly, the Colombian road network in 2006 was of approximately 166,233 km, of which 16,575 km (10%) made up the primary network, 66,082 km (39.8%) were part of the secondary network, and 36,736 km (22.1%) made up the tertiary network. In addition, 34,285 km (20.7%) under the jurisdiction of the former *Fondo Nacional de Caminos Vecinales* (National Local Roadways Fund), and 12,556 km (7.6%) were not classified (Ospina, 2004). As we can observe, secondary roadways make up an important proportion of the Colombian road network. Correct conservation and proper maintenance of all the infrastructure works within this network will improve the wellbeing of the different regions and improve quality of life for a great number of Colombians.

Projects by Fedesarrollo in Colombia have indicated that: a 1% increase in kilometers of highway is associated with a 0.42% increase in Gross Domestic Product (GDP), a 1% reduction in the cost of transportation would increase exportation by 0.5%, and that signing the Free Trade Agreement (FTA) between Colombia and the United States can generate a more than 40% increase in bilateral commercial volume (Caicedo, 2007).

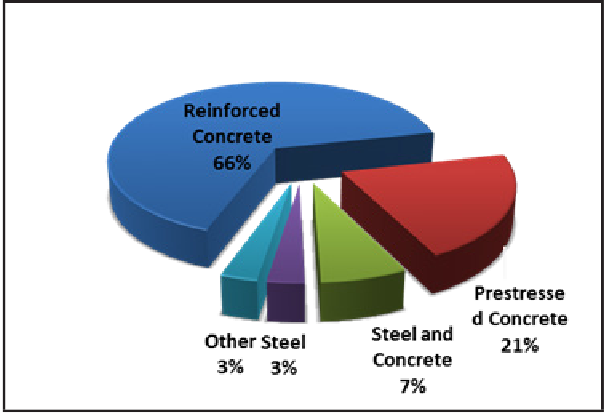
In 1996 in Colombia, the *Sistema de Administración del Mantenimiento de Puentes en Colombia* (System of Administration of Bridge Maintenance in Colombia) (SIPUCOL) was created by the *Instituto Nacional de Vías* (National Roadway Institute) (INVIAS) with assessment from the *Directorado de Carreteras* *de Dinamarca* (Denmark Directorate of Highways). It was created to develop inventory, inspection, routine maintenance, budget control, control of project progress, repair project design, and evaluation of load capacity for bridges across the national territory (Ruiz & Yamin, 2001).

The following points are the scope of the SIPUCOL system (Muñoz et al., 2005):

1. Prediction of maintenance needs and required funds.
2. Creation of lists of bridges by restoration priority.
3. Identification of bridges with restrictions or limits on service.
4. Search for the best restoration alternative.
5. Quantification of investment costs per bridge.
6. Determination of load capacity for bridges, as well as their restrictions.

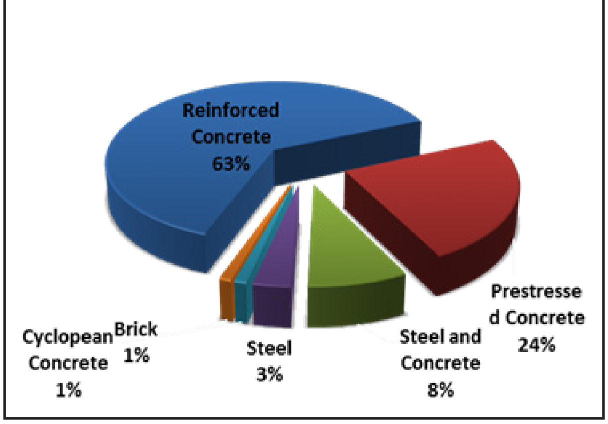
The inspection carried out in 1996 by SIPUCOL (1996) on 1,958 bridges over 10m long in the primary road network in Colombia (Ruiz & Yamin, 2001) obtained statistical values for the types of bridges across the Colombian national territory, as shown in **Figure 2**.

Figure 2. Classification statistics for bridges according to type of material in the Colombian road network (Ruiz & Yamin, 2001).



Studies developed by Muñoz et al. (2004) several years later determined that during this period, the variation in construction trends for bridges in Colombia have been maintained with regards to the initial studies conducted by SIPUCOL. In 2004, the Colombian road network had approximately 2,100 bridges, of which the greatest proportion (63%) were build with reinforced concrete, 24% with prestressed concrete, 8% with mixed superstructures (steel and concrete), and 3% with steel superstructures, as shown in **Figure 3**.

Figure 3. Statistical distribution of bridges according to construction materials (Muñoz et al., 2005)



The most common damages on the types of bridges most widely used in Colombia are (INVIAS, 2006):

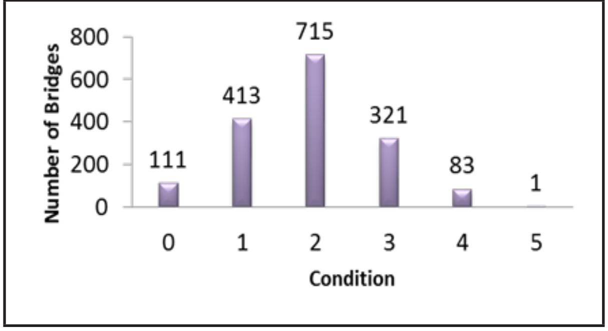
- Reinforced concrete bridges: fissures, local crushing, settling, overturning, excessive vibration, anthills, segregation, fissuring due to retraction, problems at cold joints, exposure of steel reinforcement, efflorescence, framework corrosion, contamination of concrete, failures due to impact, and undermining.

- Bridges with metal structures: corrosion, paint deterioration, loss of cable coverings, loss of tension in cables and king posts, fissures, buckling, failures due to impact, excessive deflection, poor condition of connectors, crushing, tearing, and failures in soldering.

SIPUCOL uses a scoring system parameter for the bridge conditions. This scoring system ranges from 0 to 5, with 0 representing the least damage and 5 representing extreme damage, total failure, or risk of total failure. Scores of 0, 1, and 2 are considered good conditions, 3 is considered mediocre conditions, and 4 and 5 are considered poor conditions. The bridge's final score is obtained by selecting the highest score received during the evaluation of those of its components classified as structural (Muñoz et al., 2005).

Figure 4 represents the information obtained by SIPUCOL for the Colombian road network with concrete and steel bridges.

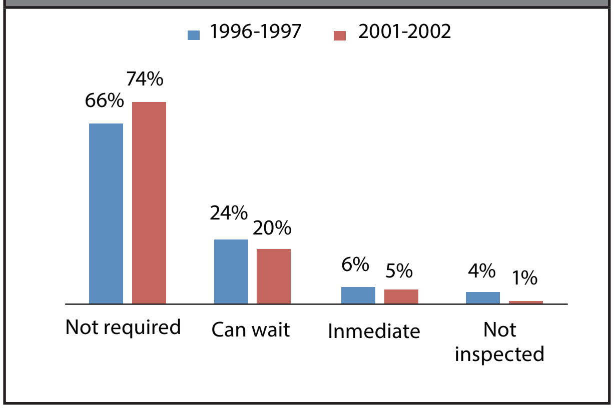
Figure 4. Conditions of bridges in the Colombian road network (Ruiz & Yamin, 2001)



Among the auscultations performed on sixty-three (63) cases of bridge collapses in the Colombian road network, it was found that 14% of the bridges failed due to structural deficiencies. The majority of these cases occurred with steel bridges (Muñoz, 2001).

After the administrative system SIPUCOL was created in Colombia, two observation periods have been established for the conditions of bridges in the Colombian road network: one from 1996-1997 (Period 1) and the other from 2001-2002 (Period 2). Within these periods, a positive evolution has been observed regarding the functional conditions of the bridges, as shown in **Figure 5**.

Figure 5. Condition of bridges in the Colombian road network during 2 SIPUCOL measurement periods (Muñoz et al., 2005).



Muñoz & Valbuena (2004) propose the following lines of research to improve the performance of metal bridges: corrosion of tension elements, wear of elements and steel joints, visual inspection with specialized equipment, deep pathology auscultation (crack-detecting microscope, extensometer, field test, quick chloride test, carbonation, equipment for monitoring cracks, ultrasound equipment for detecting coverings and reinforcement, adherence tests, etc.) and specialized undermining studies.

3. DATA COLLECTION METHOLODGY

This study is based on the collection of data between 2009 and 2012 on the 1,283 bridges that belong to secondary roadways in the Department of Antioquia, whose maintenance and conservation are the purview of the *Secretaría de Infraestructura de la Gobernación de Antioquia* (Infrastructure Secretariat of the Government of Antioquia). For the collection of data based on research established by SIPUCOL, personnel from the *Secretaría de Infraestructura* (Infrastructure Secretariat) designed the Bridge Referencing Sheet (**Figure 6**), whose main objective was to facilitate collection of the most relevant data regarding the conditions of bridge infrastructures under the purview of the Department of Antioquia.

The following was among the information collected on the sheet for each bridge: municipality, sub-region, name of roadway, abscissa, rural locale or small town in which the bridge is located, photographic documentation, bridge type, length, width, number of beams, number of supports, height of abutments, name of ravine or river crossed, structure gauge, condition of superstructure, type of intervention required, researcher responsible for retrieving information, and date of data collection.

A large percentage of the information collected pertains to quantitative values for the bridge measured on-site. The only qualitative measurement was for the condition of the different structural elements that made up the bridge and whose values were assigned after a thorough visual inspection performed by a trained professional. The final evaluation of the bridge is obtained after checking the information collected and proposing the type of intervention required for each of the bridges analyzed according to the highest score of the components evaluated (Muñoz et al., 2005).

Figure 6. Data collection sheet

BRIDGE REFERENCE SHEET

Antioquia para todos. ¡Manos a la obra!

GOBERNACIÓN DE ANTIOQUIA
Secretaría de Infraestructura Física

Municipality: *Sub-region:* *Roadway:* Abscissa

Location of bridge in rural locale, small town, community, or other - specify:

Photo of bridge:

CHARACTERISTICS OF BRIDGE OR STRUCTURE

Type of bridge or structure:
Reinforced concrete ☐ post-tensioned concrete ☐ Metal ☐ Suspension ☐
Box culvert ☐ Other-specify ______________________
Length of bridge or structure (in meters ___________ width of the bridge (in meters) _____
Number of bridge beams: ___________
Number of bridge supports: ___________

ABUTMENTS
Right margin Left margin

Total height (m)

Name of ravine or river

Structure gauge (m)

Condition of superstructure
(fissures, corrosion, accumulation of material, displacement, wear, impact, loss of support, loss of section, concrete in poor condition, exposed steel)
Condition of substructure
(undermining, fissures, displacement, wear, collapse)
Intervention required, measuring scale from 0 to 1

Intervention required, measuring scale from 0 to 1 *0 does not require* *2 immediate*
0. ☐ 1. ☐ 2. ☐

Researcher responsible for data collection DATE:

The data collected on the sheets was statistically processed, abstracting the most representative variables for follow-up and control of this type of infrastructure. This also served as a prioritized diagnostic for the professionals responsible for the correct functioning of bridges under the purview of the *Secretaría de Infraestructura de la Gobernación de Antioquia* (Infrastructure Secretariat of the Government of Antioquia).

These results will be useful for taking the necessary corrective measures and implementing a system of improvements for future bridges to be built in the Department of Antioquia. Likewise, the data collected will aid in defining the priority for investment of resources in bridges that need immediate intervention to avoid a possible collapse.

4. RESULTS

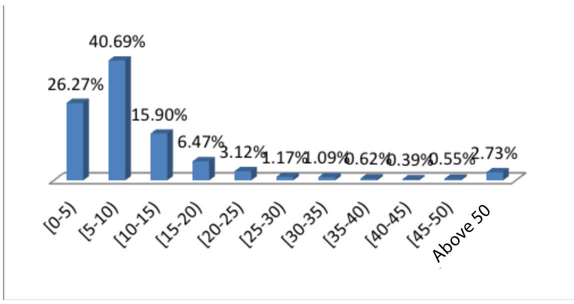
After completing a thorough data collection for each of the bridges evaluated, we statistically analyzed the different variables measured and tabulated the results graphically.

The tabulation of data was developed in such a way that the graphs show the most relevant statistical parameters for the different variables analyzed.

4.1. Representative lengths of bridges in secondary roadways

One of the most important variables that largely determine the structural type to be used in the construction of a bridge is its length. The magnitude of this variable depends mostly on the width of the obstacle to be crossed, mainly currents of natural water such as rivers or ravines. As length is a variable with constant measurement, we chose to group the measurement values in spectrums of 5 meters. **Figure 7** shows the statistical results obtained for this range of measurement.

Figure 7. Bridge statistics by length (units in meters).



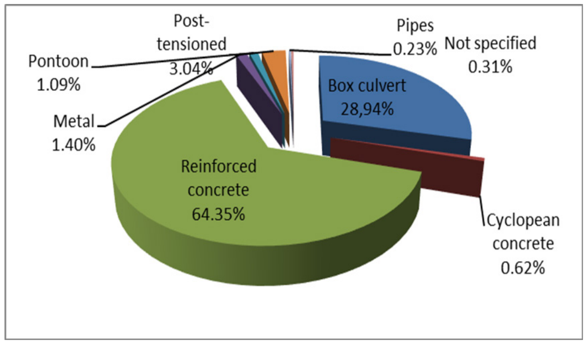
Although bridges under 5m in length are considered by some regulations to be pontoons or culverts, they are included on the table of results within the statistics obtained since they make up a significant percentage of the sample collected (26.27%), and their analysis can be of use for future research on this topic.

We can observe that a large percentage of bridges are short with distances between beams of less than 15m, the longest incidence of which is for bridges between 5m and 10m in length. These results are very useful in determining the structure systems with the best cost-benefit relationships for these most common lengths, and also for optimizing the design of this type of structure according to materials for the different regions within the department.

4.2. Types of bridges in the Department of Antioquia

Another of the variables collected within the data for bridges in secondary roadways in the Department of Antioquia was the type of its main structural system. **Figure 8** shows the statistical results of analysis of the different types of bridges in secondary roads in the department.

Figure 8. Bridge statistics by type

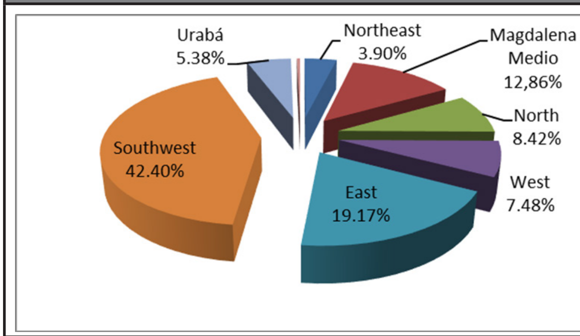


Given the characteristic length of a large percentage of these bridges, the two structures most closely adapted to these distances between beams are reinforced concrete slabs and box culverts. Due to their age, many of them were erected with other construction techniques more popular during that period, despite the fact that today it would have been more efficient to construct them with post-tensioned concrete or with a metal structure.

4.3. Inventory by sub-region

The Department of Antioquia is politically sub-divided into nine (9) sub-regions. This political sub-division was another of the variables involved in the research project in order to establish the bridge infrastructure's patrimony in the main sub-regions and their statistical distribution throughout the department. **Figure 9** shows the statistical results obtained.

Figure 9. Bridge statistics by sub-region

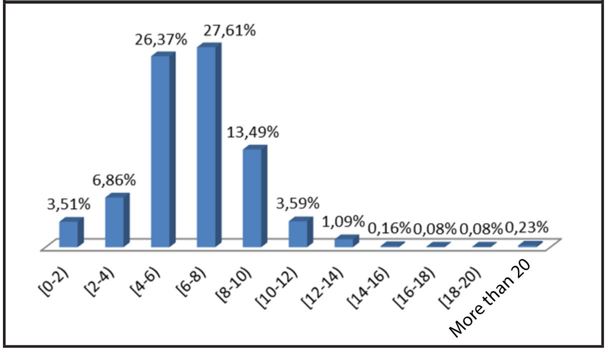


As well as serving as a statistical reference of bridges in the secondary road network in the department, the distribution of bridge infrastructure throughout the Department of Antioquia is also useful for indicating the approximate percentage of the distribution of resources for supervision, monitoring, maintenance, and repair of these structures in Antioquia. Finally, it is useful for revising conservation policies for roadway infrastructures in the different sub-regions of the Department of Antioquia.

4.4. Characteristic width of bridges in the department

Another of the characteristic dimensions of a bridge's geometry is its width. This dimension establishes vehicular capacity for the bridge and determines traffic flow for the road. **Figure 10** shows the statistical results obtained.

Figure 10. Bridge statistics by width (units in meters)

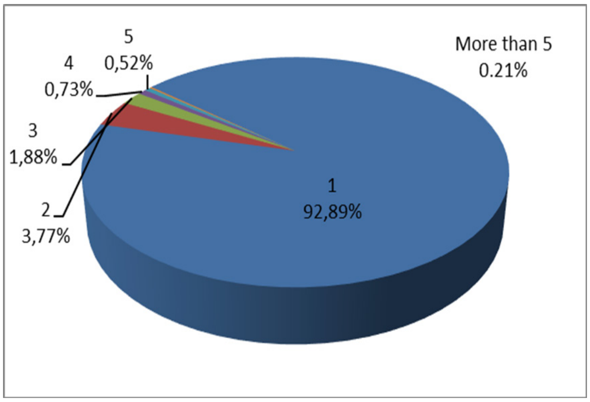


The predominant bridge width varies between 4m and 8m according to the geometric specifications for simple roads with two lanes, which are the most common in the secondary road network in the Department of Antioquia.

4.5. Distance between beams

According to the structural type of the bridge and the length of the obstacle to be crossed, the need arises to place intermediate supports that provide greater stability to the structure and notably reduce project costs. **Figure 11** shows the statistical results obtained for the measurement of this variable.

Figure 11. Bridge statistics by distance between supports

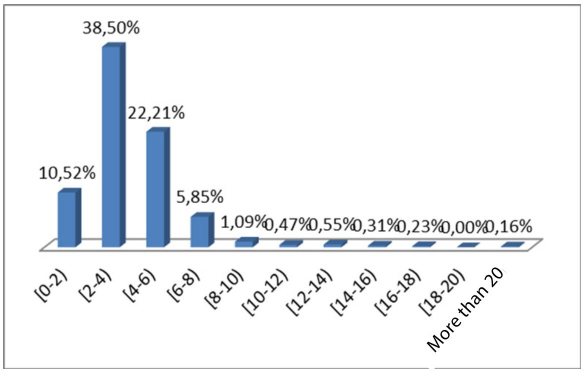


As can be observed in **Figure 11**, since short bridges are the most common, a simple support system is used on nearly all bridges that belong to the secondary road network in the Department of Antioquia.

4.6. Height of abutments

A bridge's abutments are the structures responsible for transmitting the bridge's external loads to the foundations, and from there to the supporting soil. They also serve as a containment structure for the road's access embankment. The height of these abutments is a characteristic geometric parameter for a bridge's structure. Since height is a variable with continuous behavior, the statistical results obtained were grouped into ranges of 2 meters. **Figure 12** shows the results obtained.

Figure 12. Bridge statistics by abutment height (units in meters)



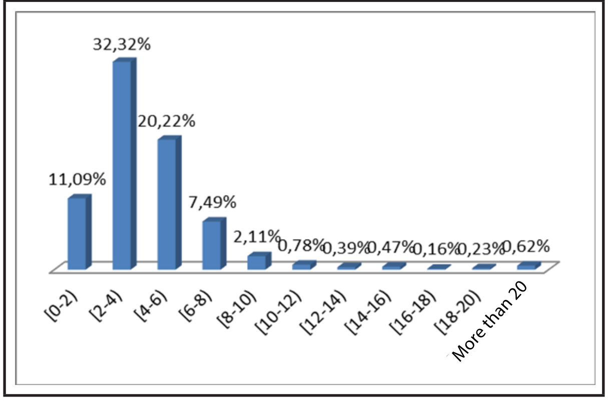
As a result of the topographical conditions of the main obstacles crossed by bridges in the secondary road network in the Department of Antioquia, the characteristic height of these abutments is between 2m and 4m.

4.7. Characteristic structure gauge of bridges in secondary roadways

The structure gauge is the free height between the lower part of the superstructure and the maximum known flood level or the maximum obstacle that must cross the full length of the bridge. In most cases, the structure gauge is a decisive parameter for establishing navigability on the bridge. It is also an important parameter for most contractors in defining the bridge's construction type since this determines its economic viability for constructing the scaffolding for the bridge's frame or creates a need for implementing launching or hoisting methodologies in construction. Like other variables measured in this study, structure gauge shows continuous behavior. The statistical results obtained are grouped into ranges of 2 meters, as shown in **Figure 13.**

Similar to what we observed with regards to the height of abutments, the characteristic structure gauge of these bridges shows an analogous statistical behavior, and the range of highest percent incidence falls between 2m and 4m high.

Figure 13. Bridge statistics by structure gauge (units in meters)



5. CURRENT BRIDGE CONDITIONS

The condition of the bridge patrimony on secondary roadways in a region is a variable that influences the development of its economy and provides qualitative parameters on mobility in the region. A large percentage of the products consumed in Colombia's department capitals are mobilized using this type of roadway. Any damage or collapse that may occur on a bridge within these roadways will cause large setbacks in the commercial development of the regions and the country, as well as affecting the quality of life of a large percentage of Colombians.

Globalization has determined that the Colombian market is not only created between its regions, but that it is also a market open to the entire world. The free trade agreements currently governing the exchange of products between Colombia and different countries around the world, among them the United States, one of the great world powers, create a need for governmental agencies that preserve and adequately maintain the entire national network of bridges, which will generate a free flow of goods and persons for the wellbeing, and the improvement of quality of life, of all Colombians.

The data collected in this study is useful for the *Secretaría de Infraestructura del Departamento de Antioquia* (Infrastructure Secretariat of the Department of Antioquia) and all those responsible for the proper functioning of the bridges in this region so that they can take corrective measures and establish a periodic maintenance program that allows for improving the structural behavior of bridges on the department's secondary roadways, thereby guaranteeing the normal flow of good and people throughout the territory of Antioquia.

5.1. Superstructure conditions

The superstructure includes all elements of a bridge that are located atop its support elements. It is generally made up of the road surface, the beams, and the upper slabs. **Figure 14** shows the report on the statistical registry of the observations made of the bridges' superstructures.

Although a large percentage of the superstructures of bridges belonging to the secondary road network of the Department of Antioquia are in good conditions, several types of functional defects were found, including normal wear due to use and the accumulation of material, which are the main factors among the defects found in the inventory.

Correct preventive maintenance of the superstructure, carried out periodically and accompanied by clean-up teams to avoid the accumulation of material and allow for free evacuation of runoff water, is a fundamental tool for guaranteeing the proper function of the superstructures of bridges on secondary roadways in the Department of Antioquia.

5.2. Sub-structure conditions

As in the case of the superstructure, a general registry of substructure conditions was performed. The substructure is the set of elements that hold the bridge up and efficiently transmit loads to the foundation soil. Among these, we can mention: columns, abutments, supports, pylons, and bridgeheads. A large percentage of the substructures are in good conditions, although the two main defects observed were the presence of fissures and undermining. **Figure 15** shows the report on the statistical registry of observations made of the bridges' sub-structures.

Although the highest percentage of the substructures evaluated are in good conditions, problems such as fissures, undermining, and accumulation of material have a high degree of participation in the measurements completed. This creates the possibility of generating new and more efficient methodologies for repairing these kinds of problems and of developing studies to create a reduction in these kinds of problems for bridges to be built in the future.

6. DEGREE OF INTERVENTION FOR BRIDGES

As a final piece of data for the technical inspection completed on each of the bridges, and after correlating the different variables measured during the inspection, a final degree of intervention to be carried out is determined for each bridge. This degree of intervention is in accordance with the qualitative scale proposed by SIPUCOL (2004), which is currently used by INVIAS. The qualitative scale used in the inventory summarized the bridge's condition in only three types of condition according to the methodologies endorsed by SIPUCOL (2004). The three conditions proposed are: zero (0) if no intervention is required, one (1) if intervention can wait, and two (2) if immediate intervention is needed. **Figure 16** shows the final result of the inspection of bridges belonging to the secondary road network of the Department of Antioquia.

Figure 14. Superstructure conditions.

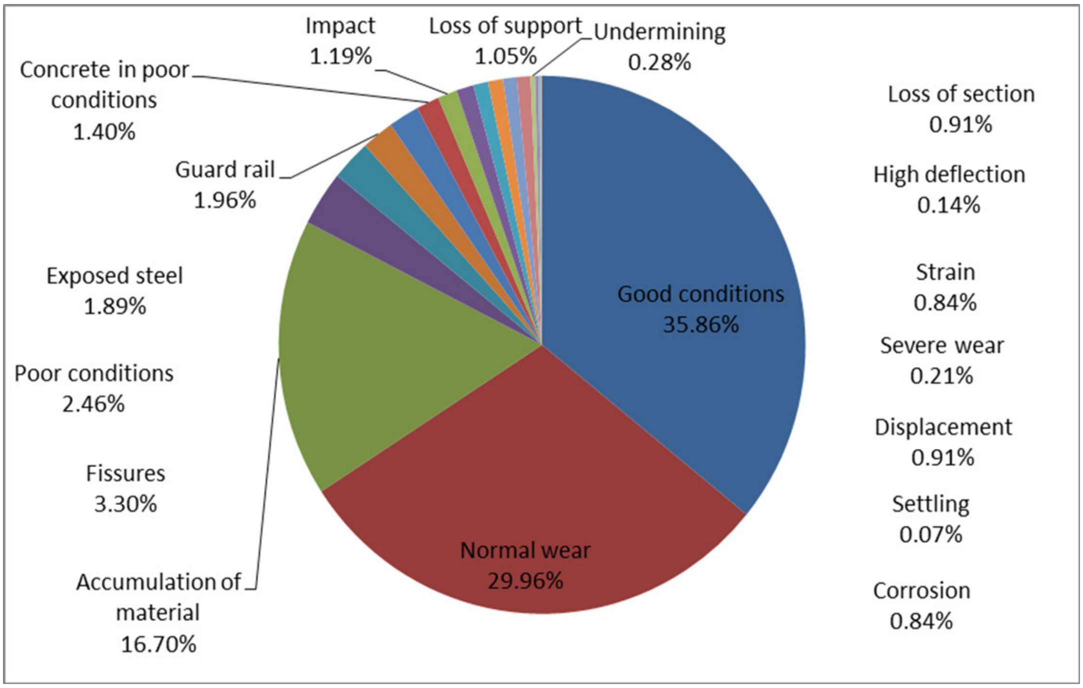
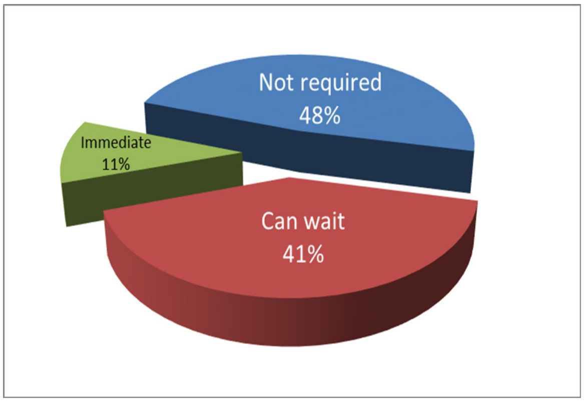


Figure 16. Degree of intervention for bridges



For the bridges that require immediate intervention, we recommend completing a specialized inspection with auscultations of the structure, including both destructive and non-destructive field and laboratory tests in order to exactly determine the condition and mechanical properties of the materials that make up the bridge, as well as defining the best alternative for repowering to be used in each case.

Thanks to the partial results of this inventory in late 2011, several bridges that required immediate intervention have already been repaired, and resources from Colombia Humanitaria have been used to construct 11 new bridges in the secondary network.

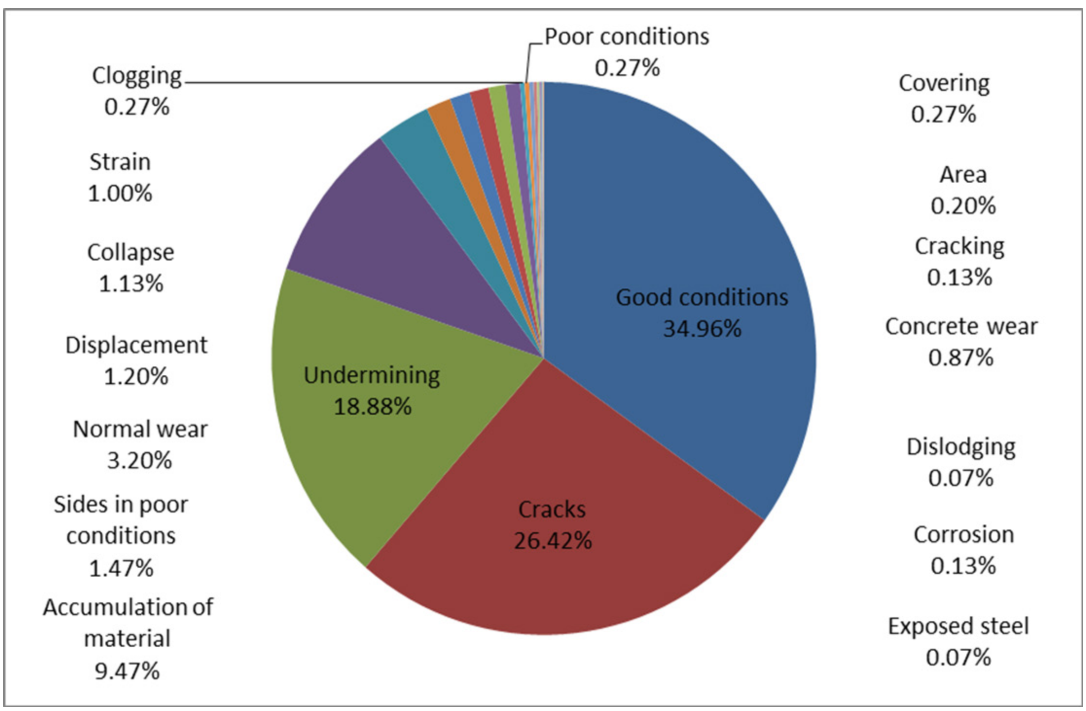
6. CONCLUSIONS

A large proportion of the bridges that belong to the secondary road network of the Department of Antioquia are of a short length. The most common length is in the range of 5-10m (40.69%), followed by a length of 0-5m (26.27%).

The main construction type for bridges in Antioquia's secondary roadways are those built with reinforced concrete (64.35%), followed by box culvert bridges (28.94%).

The regions with the highest percentage of bridge infrastructure in the secondary network for the Department of Antioquia are the southwest (42.40%) and the east (19.17%).

Figure 15. Sub-structure conditions of bridges in secondary roadways in the Department of Antioquia



More than 50% of the bridges belonging to the secondary road network of the Department of Antioquia require some type of intervention. We observed the need for implementing new intervention and monitoring techniques to decrease this percentage over time and guarantee the stability of this type of infrastructure during its service life.

The investment needed to construct one linear meter of bridge structure is very high when compared with the cost per linear meter of other types of works frequently used in roadway infrastructure. It is therefore vitally important for all agencies responsible for maintenance and construction of this type of structure to ensure adequate maintenance planning to guarantee proper functioning of these structures during their service life.

Both the height of abutments and the characteristic structure gauge of the bridges are statistically dependent variables, and their greatest concentration for the bridges in the secondary road network of the Department of Antioquia is in the range of 2-4m.

The greatest defects in the bridges' superstructures found during the inventory were normal wear (29.96%) and the accumulation of material (16.70%). The sub-structures showed the presence of fissures in 26.42% of the cases evaluated and undermining in 18.88%.

The main lesson of the winter season during the years 2010 and 2012 in Colombia is the necessity of adopting corrective measures that allow for mitigation and prevention of future impacts of adverse factors on the bridges throughout the country. In this regard, we recommend checking design parameters by consulting personnel experienced in bridge pathology and related topics so that design variables may be adjusted to the different geological, hydraulic, environmental, and seismic factors that affect the decision regarding the type of structure to be used in a bridge's construction, previously checking variables such as materials and structural system versus maintenance costs during the service life of this type of structure.

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