Recycled Roads: Plastic Pavements based on G5 Binder in California, United States

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Abstract— **Throughout the development of this work, an analysis has been carried out in which the problem of deterioration and inefficiency of routes and highways in the state of California, United States, was taken as a point of interest. This problem required the search for an efficient and lasting solution.**

Taking the latter into account, the possibility of implementing a new pavement based on recycled binders has been analysed. This binder, called Technisoil G5, gives this new flooring greater resistance and durability to be able to fulfill its function and also last longer over time. In addition to its good mechanical behavior, it should be taken into account and highlighted that it is very friendly with the environment and becomes more economical for both the State and the users.

Based on all of the above, it can be said that this type of pavement is presented as one of the most efficient solutions to the problem of inefficient roads. In addition, analyzing the advantages offered by this type of recycled asphalt, it is estimated that its implementation could soon be applied in other parts of the world.

Resumen— **A lo largo del desarrollo de este trabajo, se ha realizado un análisis en el que se tomó como punto de interés la problemática del deterioro e ineficiencia de las rutas y carreteras en el estado de california, estados unidos. Este problema requería la búsqueda de una solución eficiente y duradera.**

Teniendo en cuenta esto último, se ha analizado la posibilidad de implementación de un nuevo pavimento a base de ligantes reciclados. Este ligante, llamado Technisoil G5, dota a este nuevo pavimento de mayor resistencia y durabilidad para poder cumplir su función y además durar más en el tiempo. Ademas de su buen comportamiento mecanico, se debe tener en cuenta y resaltar que es muy amigable con el medio ambiente y se vuelve más económico tanto para el Estado como para los usuarios.

En base a todo lo anterior, se puede decir que este tipo de pavimento se presenta como una de las soluciones más eficientes al problema de las vías ineficientes. Además, analizando las ventajas que ofrece este tipo de asfalto reciclado, se estima que su implementación podría aplicarse próximamente en otras partes del mundo.

INTRODUCTION

Road infrastructure has experienced deterioration, inefficiency, and lack of durability in the United States in the recent years, particularly in the State of California. These problems associated with road infrastructure generate inconveniences in the development of society, for which related engineering organizations had to become involved in the situation. In this line, the National Academy of Engineering (NAE) reports that, one of the main challenges of civil engineering is to "[r]estore and improve urban infrastructure" [1, pp. 22-24] without neglecting the need to take care of the environment. For this reason, the use of plastic pavements based on G5 binder to construct recycled roads may be key to solve the problem of deteriorated roads in California, United States.

The proposed solution is the replacement of roads made of traditional pavements with roads made of recycled pavements based on the G5 binder. This binder has been carried out by TechniSoil, a company which developed a suitable material to bind pavement components and, at the same time, to be profitable and environmentally friendly.

The purpose of this paper is to discuss the use of the G5 binder in plastic pavements in California, United States roads. To achieve this purpose, this paper is organized as follows. First, the current conditions in which the roads are found will be discussed. Secondly, recycled pavements will be addressed. A brief reference will be made to the evolution of the types of recycled pavements. Then, TechniSoil G5 will be described. Finally, the implementation and performance of the new material will be discussed.

I. ROADS CONDITIONS

Today, roads are a very important and necessary structural part for the performance of societies. Their operation and condition are essential for the transport of goods and people. However, due to lack of funds and maintenance, the conditions of the pavements in California have greatly worsened in recent years. Their shortcomings have led to large costs for repairs, maintenance, fuel for vehicles, and dangers to the lives of its users, such as drivers and pedestrians.

In this sense, the report published by Roads Committee in 2019 makes reference to the Pavement Conditions Index (PCI). The PCI shows the current conditions of the infrastructure that respond to civil works in the country by means of a grading scale. This grading scale “is based upon a simple ‘A through F’ school report card format: ‘A’ for Exceptional, Fit for the Future, ‘B’ for Good, Adequate for Now, ‘C’ for Mediocre, Requires Attention, ‘D’ for Poor, At Risk, and ‘F’ for Failing/Critical, Unfit For Purpose” [2, p.4].

For the analysis that is intended to be carried out in this paper, only road infrastructure in the State of California will be considered. Taking into account the average of local streets and highways in California, the PCI assigned them a "D", which means that it is in "Poor: At Risk" condition. This refers to the fact that the system made up of the various

highways in the State of California is mostly in poor conditions and below the standard level, reaching the end of its useful life and generating a high risk of failure.

Everything mentioned can be seen in the figures that this result represents. Currently, California has nearly 51,000 lane miles of state highways and 335,000 lane miles of local streets and highways ranking as the second worst road infrastructure in the country. Only 19% are in good condition, leaving 68% in poor or mediocre condition, while 51% are main urban roads; and 13% in acceptable conditions. Additionally, each driver pays between $299 and $1,774 per year in costs due to driving on roads in need of repair. [2]

In relation to these figures, the country has developed a program called *Vision Zero*. It is an alliance of certain States seeking to make the streets safer by redesigning and implementing new measures and materials [3]. Particularly, California is one of the states that make up the Vision Zero program as it is one of the most affected in relation to road problems. That is probably why one of the most innovative solutions has been developed there.

II. Recycled Pavements

Of all the solutions that have been proposed to address the problem of deterioration, inefficiency, and lack of durability in road infrastructure in the United States, the development of recycled pavements was the most innovative solution.

A. Evolution

In relation to the history of road infrastructure failures, it has been concluded that the control and maintenance of pavements with new and better materials extend their useful life, making it less expensive than fixing them after they fail. In a similar vein, the total reconstruction of those highways that are already in this state of failure or aging with new materials is better than a provisional repair. In both cases, the use of new materials may be considered a solution that lasts over time and adapts to new needs and demands.

As of 2014, the use of pavements made from new materials and other recycled ones has been implemented. The so-called Recycled Asphaltic Pavements (RAP) are the mixture of aggregates and asphalts that are generated when the existing asphalts are removed. Being well extracted, crushed and sifted, RAP is considered a high-quality aggregate, although it needs a supplement to be used again. The combination of these components seeks to improve resistance to rutting and cracking. To meet the need for a binder supplement for RAP, a new binder called TechniSoil G5 was created [4].

III. TechniSoil G5 (100% RAP)

TechniSoil G5 is a bio-based asphalt mix binder that reacts with the RAP/soil/base components, forming a network of water-insoluble polymers. It was created with the aim of achieving a 100% stabilized RAP that has the best resistance to various deterioration conditions.

The 100% stabilized RAP is a system that uses ground old asphalt with the addition of a percentage of TechniSoil G5 binder that arises from a process of centrifugation and evaporation of plastic bottles with a solution of toluene and ethanol. It uses 150,000 plastic bottles from post-consumer waste to generate each lane mile.

Through a pilot test of the dynamic modulus, the stiffness of the mixture was evaluated at different load speeds and temperatures. Also, failure modes using laboratory tests such as permanent deformation, fatigue cracking and thermal cracking. [4]

1) Dynamic modulus: It is a property that measures the overall quality of the mix. This property is obtained by applying a load to the mixture and analyzing the stress-strain relationship that is generated after being subjected to different levels of frequency and temperature.

The results of the dynamic modules test were positive. They indicated that the mixture has good stability and good elastic properties, which makes it behave as a viscoelastic material similar to that of asphalt mixtures. [4]

2) Permanent deformation: This property indicates volume decrease, density increase and shear deformation under certain conditions. The permanent deformation test is a performance teste to evaluate the resistance to rutting which is produced by gradually applied loads of great magnitude. What is sought by means of this characteristic tested is to avoid longitudinal depressions with their lateral elevations that generally occur in the tracks marked on the rail by the wheels.

The results of this test were also favorable. Subjecting the 100% stabilized RAP mix to repeated axial compression pulse loading at fixed time intervals with breaks in between, it was found to be excellent at withstanding all levels of traffic regardless of unfavorable weather, such as hot weather. [4]

3) *Fatigue cracking:* It is a characteristic that seeks to know how capable the mixture is to withstand repeated loads without cracking. This is one of the most common failures due to aging since the pavement loses its elastic behavior.

The test also had positive results in this aspect. The test was performed by subjecting a beam-shaped specimen to bending at four points with free rotation and translation, in repeated constant periods, until failure occurred. This took place at the point of 50% reduction of the initial stiffness. As a result, it was concluded that the mixture presents a very good flexural fatigue ratio. [4]

4) *Thermal cracking:* It is a characteristic that shows the pavement behavior against low temperatures. These cause large tensile stresses to be induced in the mix by restrained shrinkage, which is why cracks form through the depth of the asphalt layer.

The material also presented favorable results in the thermal cracking test. Subjecting the 100% stabilized RAP mixture to a uniaxial thermal stress and strain, the accumulations of these were measured after a cooling process at a set rate. The results obtained indicated that the mixture has an ability to withstand a low fracture

temperature while maintaining a relatively high fracture stress, thus being well resistant to thermal cracking. [4]

IV. Implementation and Performance

Regarding the implementation of the 100% stabilized RAP, the greatest changes produced are in relation to the impact on the environment. Linking traditional pavements with those manufactured with 100% RAP, the environmental impact reduction is given by different aspects. These are related to a 90% reduction of greenhouse gas emissions; zero negative impact on water, air and soil; zero consumption of new materials and resources due to the reuse of existing asphalt; and total energy reduction [5].

Apart from this positive impact on the environment, the advantages of using this innovative mixture are due to its general behavior in relation to traditional pavements. These new pavements, last 2 to 3 times longer than traditional asphalt and have 5 times the tensile strength of ordinary asphalt with higher flex properties. As well as this, they have zero fluidity, and their compressive strength is similar to that of concrete and they also eliminate rutting and provide extremely high resistance to flex cracks. In addition, they offer at least 50% savings in the life cycle to taxpayers [5].

In general, the 100% RAP mix with TechniSoil G5 behaves better than the traditional pavements made up to now. This is because its resistance to critical damage is very good and its collaboration with the environment is much greater.

V. Conclusion

In conclusion, the use of this type of recycled asphalt is highly beneficial for the development of road infrastructure. This is because in addition to being favorable in environmental terms, reducing the use of natural resources and taking advantage of waste, its efficiency is greater than that of traditional asphalts. This complies with the need to improve urban infrastructure with little to no environmental impact, as posed by the National Academy of Engineering challenges.

The participation of engineers in the solution to the challenge of restoring and improving the quality of roads is very important. In this respect, civil engineers are those who have the knowledge and skills to make innovative changes possible, favoring future generations and contributing to the development of a better world.

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