UNIVERSIDAD CATÓLICA SANTO TORIBIO DE MOGROVEJO
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A sustainable alternative for reclaimed asphalt pavement (RAP) as an addition in granular bases

TRABAJO DE INVESTIGACIÓN PARA OPTAR EL GRADO ACADÉMICO DE BACHILLER EN INGENIERÍA CIVIL AMBIENTAL

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Resumen

Los pavimentos asfalticos recuperados (RAP) en los últimos años se han convertido en una práctica común para la rehabilitación y/o mantenimiento de carreteras en el mundo como sustituto de los agregados naturales. En la presente investigación se evaluó la influencia de la incorporación de RAP en las propiedades físicas y mecánicas de bases granulares para pavimentos flexibles. El RAP de 4 sectores se mezcló con material de cantera en dosificaciones de 5% y 10% por peso de la mezcla. Los ensayos de laboratorio que se utilizaron para caracterizar las muestras de RAP fueron: granulometría, abrasión de los ángeles y contenido de asfalto; mientras que a las dosificaciones se les añadió otros ensayos como: equivalente de arena, caras fracturadas, proctor modificado, relación de carga de california (CBR), sales solubles totales y para ensayos de campo, densidad mediante el cono de arena y DCP in-situ. Además, se realizó un análisis técnico del uso de RAP para evaluar su viabilidad en proyectos viales. Al finalizar la investigación se concluye que, con las dosificaciones estudiadas de RAP, disminuye la densidad máxima seca insignificantemente con respecto a la muestra patrón, los valores de CBR aumentan en laboratorio e in-situ mediante la correlación por ensayo DCP, el equivalente de arena aumenta, el porcentaje de abrasión aumenta, el porcentaje de sales solubles se mantiene. Concluyendo que la adición de RAP con material de cantera produce una base granular de mejor calidad para su uso en bases granulares de carreteras.

Palabras clave: base granular, pavimento asfaltico recuperado, CBR, pavimento

Abstract

Reclaimed asphalt pavements (RAP) in recent years have become a common practice for the rehabilitation and/or maintenance of roads in the world as a substitute for natural aggregates. In the present investigation, the influence of the incorporation of RAP on the physical and mechanical properties of granular bases for flexible pavements was evaluated. The 4-sector RAP was mixed with quarry material in dosages of 5% and 10% by weight of the mixture. The laboratory tests used to characterize the RAP samples were grain size, Los Angeles abrasion and asphalt content; while other tests were added to the additions, such as: sand equivalent, fractured faces, modified proctor, California bearing ratio (CBR), total soluble salts and density field tests using the sand cone and DCP in-situ. In addition, a technical analysis of the use of RAP was carried out to evaluate its viability in road projects. At the end of the testing stage that, with the addition of RAP, the maximum dry density decreases insignificantly with respect to the standard sample, the CBR values increase in the laboratory and in-situ by means of the correlation by DCP test, the equivalent of sand increases, the percentage of abrasion increases, the percentage of soluble salts remains the same. Concluding that the addition of RAP with quarry material produces a better quality granular base for use in granular road bases.

Keywords: granular base, reclaimed asphalt Pavement, CBR, Pavement.

Introduction

Road infrastructure worldwide is comprised of 21 million kilometers [1] and related industrial sectors are responsible for approximately 24% of global green-house gas (GHG) emissions on the planet [2, 3]. Natural aggregates are non-renewable sources and make up a high percentage of pavements, a small recycling of these can reduce the environmental impact of road infrastructures. Various investigations are currently being carried out for the recycling of aggregates.

Among the most used recycled aggregates on roads are concrete waste (WC) and recovered asphalt pavement (RAP) [4].

The RAP is a surplus material that is generated during the rehabilitation of flexible pavements, in Europe and the United States around 100 million tons were produced in 2017, however, in Europe 68% of RAP is reused for new asphalt mixtures, 19% is reused in the underlying granular layers, 1.25% is used in other projects related to civil engineering and 11% goes to the dumps [5]. The data for Peru is a bit outdated due to the lack of a recycling policy.

Some research focuses its theme on granular bases with RAP dosage, being or not of the fundamental parameters for the design of granular bases is the CBR, according to [6] this value tends to decrease when the proportion of RAP exceeds approximately 20% of content, it is also observed that the value of CBR decreases when the content of RAP is in-creased [7, 8, 9, 10, 11, 12, 13]. [14] analyzed the physical resistance and cutting properties of 100% RAP in its granulometry of gravel, sand, and fines; concluding that it does not meet the minimum requirements to be used as a material for granular base and it is recommended to use modifying additives. [15] and their research compared and analyzed RAP dosages in a range of 10% to 100% with quarry aggregate and recommended 30% RAP as the optimal dosage for use on a granular basis meeting all minimum requirements by the Ministry of Road Transport and Highways (MORTH). Therefore, the background shows that the use of RAP can be viable as a base material due to the cost-effectiveness compared to quarry material and its resistance to failure by hollowing out a traditional base layer.

To promote the recycling of RAP as a sustainable strategy with respect to pavement materials, the following hypothesis is proposed: the dosages of RAP in values of 5% and 10% preserves the properties of granular pavement bases according to the EG-2013 General Technical Specifications [16] and CE 010 Urban pavements [17].

Methodology

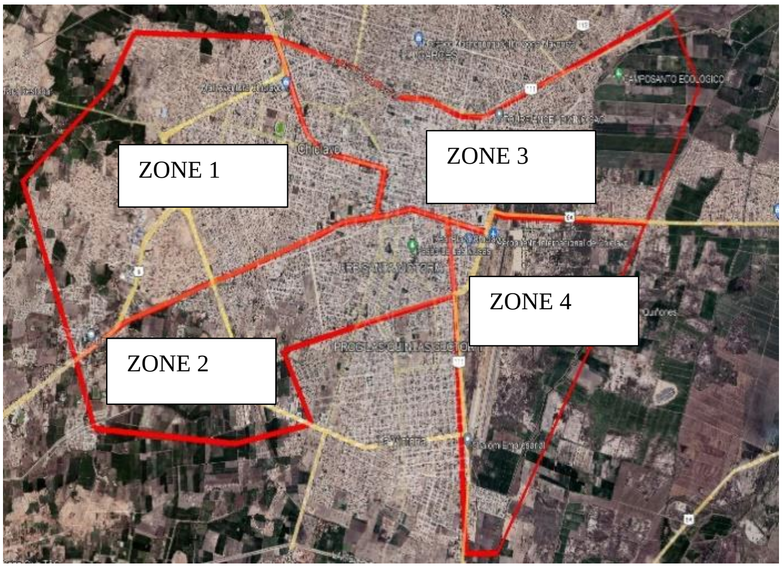
The present research was experimental.

Obtaining RAP

The obtaining of the RAP samples was collected within the area of the city of Chiclayo, delimited in 4 sectors, being 3 samples of 100 kg per-sector, forming a total of 12 CAR samples which will be characterized by granulometry and abrasion of the angels.

The sizes to be used of RAP in the dosages are those retained between the mesh 3/4" and N°60.

Figure 1. Sectorization of the city of Chiclayo



Source: Author

Obtaining Quarry Material

The sample was obtained from the Hitos – La Cria quarry located in the southeast of the department of Lambayeque 45 minutes from the city of Chiclayo, the representative sample was 500 kg which were moved in bags to the laboratory.

Dosages of RAP and quarry material

The 2 dosages of 5% RAP and 95% quarry material, 10% RAP and 90% quarry material are established based on international background and in the search to maintain the properties of the quarry material for a use optimum.

Tests carried out

The tests to be carried out will be those that will determine if the standard sample and the dosages of 5% RAP and 95% quarry material, 10% RAP and 90% quarry material comply with current regulations, the following will be considered:

- Particle size (MTC E 107)
- Atterberg limits (MTC E 108)
- Abrasion of the Angels (MTC E 207)
- Sand Equivalent (MTC E114)
- Fractured faces (MTC E 210)
- Total Soluble Salts (MTC E 219)
- Modified Proctor (MTC E 115)
- CBR in the laboratory (MTC E 132)
- In-situ DCP (ASTM D 6951)

Justification of the investigation

In the search for new alternatives for a sustainable pavement design, this research is proposed to reduce the volumes to be exploited in the quarries of the city of Chiclayo, which has several tons of asphalt pavement to be recycled in future rehabilitation projects, reducing the surplus material that is finally disposed to informal dumps polluting the environment.

Results

Below, the results obtained from the tests carried out in the laboratory are shown and a comment will be given for each of these.

Table 1 shows the results of the granulometry test for the characterization of RAP, having as its main characteristic percentages of between 37.7% and 57.4% of gravel; between 36.3% to 65.6% of sand and in a range of 4.2 to 14.8% of silt and clays; being considered good quality material and being within the minimum requirements for granular base according to [16, 17].

Table 1. RAP Granulometry

SIEVING GRANULOMETRY TEST FOR RAP SAMPLES				
DESCRIPTION		% GRAVEL	%SAND	%SILT-CLAY
SECTOR 1	SEC01-M01	45,81	49,96	4,23
	SEC01-M02	46,02	43,91	10,07
	SEC01-M03	45,02	45,86	9,12
SECTOR 2	SEC02-M01	57,42	37,34	5,24
	SEC02-M02	21,11	65,56	13,22
	SEC02-M03	40,23	52,34	7,43
SECTOR 3	SEC03-M01	21,18	64,07	14,75
	SEC03-M02	24,08	62,36	13,56
	SEC03-M03	40,25	52,94	6,81
SECTOR 4	SEC04-M01	50,80	36,25	12,74
	SEC04-M02	37,73	54,79	7,47
	SEC04-M03	46,68	43,98	9,34

Source: Author

Table 2 has the percentages of asphalt content for the 12 RAP samples, having values in a range 8.27% to 10.21%, these values depend on the particle size distribution of the sample because for sizes greater than 1" the aggregates have more asphalt coating than the smaller sizes.

Table 2. RAP asphalt content

QUANTITATIVE ASPHALT EXTRACTION		
DESCRIPTION		**% ASPHALT CONTENT**
SECTOR 1	SEC01-M01	9,92
	SEC01-M02	8,82
	SEC01-M03	9,18
SECTOR 2	SEC02-M01	8,95
	SEC02-M02	9,26
	SEC02-M03	9,12
SECTOR 3	SEC03-M01	9,35
	SEC03-M02	8,95
	SEC03-M03	9,19
SECTOR 4	SEC04-M01	10,21
	SEC04-M02	9,15
	SEC04-M03	8,27

Source: Author

Table 3 shows the percentages obtained in the angel abrasion test which indicates the resistance to wear, having as values in a range of 33.70% to 38.4% which complies with current regulations. According to the observation during the tests it can be defined that it is also related to the coating of aggregates with asphalt content, because it wears more easily.

Table 3. RAP Angels Abrasion

ABRASION OF THE ANGELES		
DESCRIPTION		**% WEAR**
SECTOR 1	SEC01-M01	38,40%
	SEC01-M02	34,30%
	SEC01-M03	35,20%
SECTOR 2	SEC02-M01	33,90%
	SEC02-M02	36,00%
	SEC03-M03	33,00%
SECTOR 3	SEC03-M01	34,10%
	SEC03-M02	35,70%
	SEC03-M03	37,60%

	SEC04-M01	34,60%
SECTOR 4	SEC04-M02	34,80%
	SEC04-M03	33,70%

Source: Author

Table 4 shows that the CBR values increase with respect to the standard sample up to a value of 12.20% and it can also be seen that the maximum dry density decreases by 0.142 g/cm^3 at most.

Table 4. Results of physical, chemical, and mechanical tests of the sample 1 of the 4 sectors. (5% RAP AND 95% Quarry material)

TEST		RESULTS OF SAMPLES TESTED 5% RAP +95% MAT. QTY				MAT CANT. 100%
		Sec01 M01	Sec02 M01	Sec03 M01	Sec04 M01	
Granulometry		Gradation B	Gradation A	Gradation A	Gradation A	Gradation A
Liquid Limit		20,00%	19,00%	19,00%	20,00%	24,00%
Plasticity Index		4,00%	4,00%	3,00%	4,00%	3,00%
SUCS		Gp	Gp	Gw	Gp	Gp
AASHTO		A-1 -a(0)	A-1 -a(0)	A-1 -a(0)	A-1 -a(0)	A-1 -a(0)
Total Soluble Salts		-	-	-	-	0,23
Abrasion Los Angeles		36,70%	37,20%	36,90%	37,10%	32,20%
Sand Equivalent		37,00%	36,00%	36,00%	38,00%	35,00%
Fractured particles	1 Side	81,20%	81,40%	83,00%	81,00%	81,10%
	2 Faces	72,10%	69,60%	77,40%	72,80%	69,60%
Modified Proctor	MDD (gr/cm^3)	2,143	2,239	2,149	2.1360	2,278
	OCH (%)	4,38%	5,07%	4,90%	5,26%	6,87%
CBR		124.2%	118.2%	112.7%	122.3%	110.7%

Source: Author

Table 5 shows that the CBR values increase with respect to the standard sample up to a value of 24.21% and it can also be seen that the maximum dry density decreases 0.145 gr/cm^3 as maximum, with respect to the DCP assay to correlate with the CBR, we can see that it is values close to the CBR obtained in the laboratory.

Table 4. Results of physical, chemical, and mechanical tests of sample 1 of the 4 sectors. (10% RAP AND 90% Quarry material)

TEST		**RESULTS OF SAMPLES TESTED 10% CAR +90% MAT. QTY**				**MAT CANT. 100%**
		Sec01 M02	**Sec02 M02**	**Sec03 M02**	**Sec04 M02**	
Granulometry		Gradation B	Gradation A	Gradation A	Gradation A	Gradation A
Liquid Limit		21,00%	20,00%	20,00%	20,00%	24,00%
Plasticity Index		4,00%	3,00%	4,00%	4,00%	3,00%
SUCS		GP-GC	Gp	Gp	Gp	Gp
AASHTO		A-1 -a(0)	A-1 -a(0)	A-1 -a(0)	A-1 -a(0)	A-1 -a(0)
Total Soluble Salts		-	-	-	0,27	0,23
Abrasion Los Angeles		39,20%	37,10%	37,30%	38,20%	32,20%
Sand Equivalent		40,00%	39,00%	39,00%	40,00%	35,00%
Fractured particles	1 Side	84,00%	84,50%	85,90%	87,10%	81,10%
	2 Faces	77,80%	77,70%	73,20%	73,40%	69,60%
Modified Proctor	MDD (gr/cm3)	2,169	2,197	2.133	2,182	2,278
	OCH (%)	5,09%	4,92%	4,87%	4,97%	6,87%
CBR		124.2%	130.0%	125.6%	137.5%	110.7%
DCP In Site		-	-	-	136.54%	111.35%

Source: Author

Conclusions

Based on the results obtained in the laboratory tests for the standard sample and the dosages of 5% RAP and 95% quarry material, 10% RAP and 90% quarry material, at 100% of its maximum dry density the following is concluded:

The 12 samples of RAP were collected from the streets of the 04 sectors (3 of each), it was verified that all comply with the percentage of abrasion, likewise they were performed a manual crushing complying with the granulometries established for use in granular base, selecting the sizes retained in the mesh 3/4 "and N° 60 for its dosage with the quarry material, with respect to the asphalt content there was a variation of between 8.27% and 10.21%, selecting the highest values of asphalt content for each sector.

With respect to the results obtained from the characterization of the RAP, it is concluded that these show some similarity with the results of the antecedents used in this research.

It is concluded from the results of granulometry that for the dosages of 5% and 10% RAP, all comply with the provisions of current regulations, being classified as type A and B.

It is concluded that the liquid limit decreases from 24% to 19% with the addition of RAP, because in the granulometry distribution the percentage of sands increases with respect to the standard sample (quarry material).

It is concluded that the percentages of the angel abrasion test tend to rise with the increase in dosages reaching a value of 39.20%, because it wears easily due to the presence of asphalt, this limits its dosage in percentages greater than 10% because Peruvian regulations limit a maximum wear of 40%.

It is concluded that the CBR with respect to dosages tends to increase, with 5% of RAP increases 12.20% and with 10% of RAP increases 24.21% compared to the standard sample at 100% of its maximum dry density.

It is concluded that the optimal dosage is 10% RAP and 90% quarry material, complying with the regulations [16, 17], obtaining a CBR value of 137.50% in the laboratory at 100% of its maximum dry density.

It is concluded after performing a small section of application in the field of dimensions of 1.20m x 1.20m x 0.3m deep and through the DCP test is correlated or a CBR of 112.01% for the quarry material and 135.58% for the dosage 10% RAP and 90% material quarry.

It is concluded, after analyzing all the results of the tests that the use of RAP is technically feasible in granular base layers of flexible pavements, demonstrating the hypothesis of the research where it preserves the physical and mechanical properties of a granular base.

Finally, we conclude that if you can use the RAP as dosage for granular bases in 10%.

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References

[1] World Bank Group, "GRIP (Global Roads Inventory Project)-2018", 2018. https://datacatalog.worldbank.org/search/dataset/0040289

[2] C. Plati, "Sustainability factors in pavement materials, design, and preservation strategies: a literature review", *Construction and Building Materials*, 211, 539–555, June 2019. https://doi.org/10.1016/j.conbuildmat.2019.03.242

[3] International Energy Agency, "Improving the sustainability of passenger and freight transport", *IEA*, 2021. https://www.iea.org/

[4] V. Antunes, A.C. Freire, J. Neves, "A review on the effect of RAP recycling on bituminous mixtures properties and the viability of multi-recycling", *Construcción Mate,* 211, 453–469, June 2019. https://doi.org/10.1016/j.conbuildmat.2019.03.258

[5] European Asphalt Pavement Association, "Asphalt in figures in 2017", *EAPA*, 2017. https://eapa.org/asphalt-in figures/

[6] E. J. Mcgarrah, "Evaluation of Current Practices of Reclaimed Asphalt Pavement/Virgin Aggregate as Base Course Materia". M. S. Thesis, University of Washington, USA, 2007. http://www.wsdot.wa.gov/research/reports/fullreports/713.1.pdf

[7] N. Garg, M. R. Thompson, "Lincoln Avenue Reclaimed Asphalt Pavement Base Project", *Transportational Research Record*, 89–95, 1996. https://doi.org/10.1177/0361198196154700113

[8] C. Luo, "High performance granular base and subbase Materials incorporating reclaimed asphalt concrete pavement". M. S. Thesis, McMaster University, Canada, 2014. http://hdl.handle.net/11375/15481

[9] P. K. Kolay, P. Singh, "Resilient modulus of a blended mixture of recycled asphalt Pavement and natural aggregate as road Pavement base material", *Geo-Chicago*, 677–686, 2016. https://doi.org/10.1061/9780784480137.064

[10] T. Bennert, A. Maher, "The development of a performance specification for granular base and subbase material". *Piscataway (NJ): Department of Civil and Environmental Engineering, Center for Advance Infrastructure and Transportation (CAIT)*, Rutgers University, USA, 2005. Microsoft Word - RAP-RCA Final Report - Final Edit.doc (rutgers.edu)

[11] R. Taha, G. Ali, A. Basma, O. Al-Turk, "Evaluation of reclaimed aspahlt Pavement aggregate in road bases and subbases", *Transportation Research Record: Journal of the Transportation Research Board*, 1652:264–9, 1999. https://doi.org/10.3141/1652-33

[12] A. Alotaibi, S. El-Badawy, M. A. Elshabrawy, "Ashpalt Pavement recycling as a subbase layer for the Egyptian roads", Journal *of Environmental Science*, Vol. 40, No 1, pp. 1-13, 2011. https://www.academia.edu/23839004/Asphalt_Pavement_Recycling_as_a_Subbase_Layer_for_the_Egyptian_Roads

[13] D. A. Cooley, "Effects of reclaimed aspahlt Pavement on mechanical properties of base material". M. S. Thesis, Brigham Young University, USA, 2005. https://scholarsarchive.byu.edu/etd/696

[14] A. Arulrajah, M. M. Disfani., S. Horpibulsuk, C. Suksiripattanapong, N. Prongmanee "Physical properties and shear strength responses of recycled construction and demolition materials in unbound Pavement base/subbase applications", *Construct. Build. Mater*, 58, 245–257, 2014. https://doi.org/10.1016/j.conbuildmat.2014.02.025

[15] B. Mishra, "A study on use of reclaimed asphalt Pavement (RAP) materials in flexible pavements", *Int. J.Innov. Res. Sci Eng. Techno*, 4, 12170 – 12177, 2015. 10.15680/IJIRSET.2015.0412088

[16] Ministerio de Transportes y Comunicaciones, "Especificaciones técnicas generales para construcción EG-2013", 2013. MC-01-13 Especificaciones Tecnicas Generales para Construcción - EG-2013 - (Versión Revisada - JULIO 2013).pdf (mtc.gob.pe)

[17] Ministerio de vivienda, construcción y saneamiento, "Norma técnica de edificación CE 0.10 Pavimentos urbanos", 2010. Pavimentos_Urbanos.pdf (construccion.org)