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Reclaimed Asphalt Pavement-A Review

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Abstract— **This document presents a review of the experimental studies done to characterize the mechanical behaviour of bituminous mixtures containing high rate of Reclaimed Asphalt Pavement. The various research on this regard is summarized in this review document.**

Keywords— **Reclaimed Asphalt Pavement, Mechanical performance, Recycling, high performance mix.**

I. Introduction

Every year, construction and reconstruction of road pavements imply a considerable consumption of valuable and non-renewable natural resources and, in particular, the component materials of bituminous mixtures: bitumen and, above all, mineral aggregate. Furthermore, maintenance work on road networks involves the production of high quantities of discarded materials coming from degraded bituminous pavements, with severe environmental consequences related to their transport to the landfill site.

The widespread consideration of Reclaimed Asphalt Pavement (RAP) materials for roadway construction began during the 1970s, the application of RAP has increased with the development of new technologies. RAP is considered to be a cost effective pavement construction material which is placed in pavements at increasing percentages.

The advantages of using RAP in new bituminous mixes is that it is economical, energy saving and environmental benefits derived from a reduction in disposal of waste from road maintenance and rehabilitation processes. A further advantage is that road thickness and geometry can be maintained.

This review is aimed to assess some of the research done in this regard, understand the process and to institute any kind of changes if necessary as well as summarize the whole concept of RAP in new bituminous mixes.

II. Reclaimed Asphalt Pavement

A. Origin

Reclaimed asphalt pavement (RAP) is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement.

Asphalt pavement is generally removed either by milling or full-depth removal. Milling entails removal of the pavement surface using a milling machine, which can remove up to 50 mm (2 in) thickness in a single pass. Full-depth removal involves ripping and breaking the pavement using a rhino horn on a bulldozer and/or pneumatic pavement breakers. In most instances, the broken material is picked up and loaded into haul trucks by a front-end loader and transported to a central facility for processing. At this facility, the RAP is processed using a series of operations, including crushing, screening, conveying, and stacking.

Although the majority of old asphalt pavements are recycled at central processing plants, asphalt pavements may be pulverized in place and incorporated into granular or stabilized base courses using a self-propelled pulverizing machine. Hot in-place and cold in-place recycling processes have evolved into continuous train operations that include partial depth removal of the pavement surface, mixing the reclaimed material with beneficiating additives (such as virgin aggregate, binder, and/or softening or

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rejuvenating agents to improve binder properties), and placing and compacting the resultant mix in a single pass.

B. *MATERIAL PROPERTIES*

1) Physical Properties

The properties of RAP are largely dependent on the properties of the constituent materials and the type of asphalt concrete mix (wearing surface, binder course, etc.). There can be substantial differences between asphalt concrete mixes in aggregate quality, size, and consistency. Since the aggregates in surface course (wearing course) asphalt concrete must have high resistance to wear/abrasion (polishing) to contribute to acceptable friction resistance properties, these aggregates may be of higher quality than the aggregates in binder course applications, where polishing resistance is not of concern.

Both milling and crushing can cause some aggregate degradation. The gradation of milled RAP is generally finer and more dense than that of the virgin aggregates. Crushing does not cause as much degradation as milling; consequently, the gradation of crushed RAP is generally not as fine as milled RAP, but finer than virgin aggregates crushed with the same type of equipment.

The particle size distribution of milled or crushed RAP may vary to some extent, depending on the type of equipment used to produce the RAP, the type of aggregate in the pavement, and whether any underlying base or subbase aggregate has been mixed in with the reclaimed asphalt pavement material during the pavement removal.

The physical and mechanical properties of RAP is as given below:

Physical and mechanical properties of reclaimed asphalt pavement (RAP).

Type of Property	RAP Property	Typical Range of Values
Physical Properties	Unit Weight	1940 - 2300 kg/m^3 (120-140 lb/ft$^{3)}$
	Moisture Content	Normal: up to 5% Maximum: 7-8%
	Asphalt Content	Normal: 4.5-6% Maximum Range: 3-7%
	Asphalt Penetration	Normal: 10-80 at 25°C (77°F)
	Absolute Viscosity or Recovered Asphalt Cement	Normal: 4,000 - 25,000 poises at 60°C (140°F)
Mechanical Properties	Compacted Unit Weight	1600 - 2000 kg/m^3 (100-125 lb/ft^3)
	California Bearing Ratio (CBR)	100% RAP: 20-25% 40% RAP and 60% Natural Aggregate: 150% or higher

2) Chemical Properties

Mineral aggregates constitute the overwhelming majority (93 to 97 percent by weight) of RAP. Only a minor percentage (3 to 7 percent) of RAP consists of hardened asphalt cement. Consequently, the overall chemical composition of RAP is essentially similar to that of the naturally occurring aggregate that is its principal constituent.

Asphalt cement is made up of mainly high molecular weight aliphatic hydrocarbon compounds, but also small concentrations of other materials such as sulfur, nitrogen, and polycyclic hydrocarbons (aromatic and/or naphthenic) of very low chemical reactivity. Asphalt cement is a combination of asphaltenes and maltenes (resins and oils). Asphaltenes are more viscous than either resins or oils and play a major role in determining asphalt viscosity. Oxidation of aged asphalt causes the oils to convert to resins and the resins to convert to asphaltenes, resulting in age hardening and a higher viscosity binder.

3) Mechanical Properties

The mechanical properties of RAP depend on the original asphalt pavement type, the method(s) utilized to recover the material, and the degree of processing necessary to prepare the RAP for a particular application. Since most RAP is recycled back into pavements, there is a general lack of data pertaining to the mechanical properties for RAP in other possible applications.

The compacted unit weight of RAP will decrease with increasing unit weight, with maximum dry density values reported to range from 1600 kg/m3 (100 lb/ft3) to 2000 kg/m3 (125 lb/ft3).(8) California Bearing Ratio (CBR) values for RAP material containing trap rock aggregate have been reported in the 20 to 25 percent range. However, when RAP is blended with natural aggregates for use in granular base, the asphalt cement in the RAP has a significant strengthening effect over time, such that specimens containing 40 percent RAP have produced CBR values exceeding 150 after 1 week.

III. Literature Review

A. Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP)

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This paper presents an experimental study to characterize the mechanical behaviour of bituminous mixtures containing high rates of reclaimed asphalt pavement (RAP). Two semi-dense mixtures of 12 and 20 mm maximum aggregate size and containing 40% and 60% RAP, respectively (S-12 and S-20, in accordance with Spanish specifications), which were used for rehabilitation of a highway section, were evaluated. First, the effect of RAP variability on the recycled mixtures was analyzed. Their mechanical properties were then studied by determining the stiffness modulus and indirect tensile strength and cracking and fatigue behaviour. Results show that high rates of recycled material can generally be incorporated into bituminous mixes by proper characterization and handling of RAP stockpiles.

B. Evaluation of high modulus mixture behaviour with high reclaimed asphalt pavement (RAP) percentages for sustainable road construction

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The aim of this work is to characterize the behaviour of high modulus bituminous mixes with low penetration grade bitumen and high reclaimed asphalt pavement (RAP) percentages. Four mixtures with RAP percentages of 0%, 15%, 30% and 50%, respectively, were analyzed. Their volumetric and mechanical characteristics were evaluated for several binder contents to define a job mix formula for real scale testing. Mechanical properties included stiffness modulus, toughness, moisture sensitivity, resistance to rutting and fatigue resistance. The most important conclusion is that it is possible to prepare high modulus mixtures (HMM) with high RAP contents and good mechanical properties similar to those of conventional high modulus mixes. However, preparation in non-adapted plants, where RAP is not previously heated, allows a maximum RAP percentage of approximately 30% only.

C. The determination of mechanical performance of laboratory produced hot mix asphalt mixtures using controlled RAP and virgin aggregate size fractions

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This study investigates the influence of fractionated reclaimed asphalt pavement (RAP) materials on asphalt mixture performance. The RAP mixture percentages used were 15%, 35%, and 50% in the study. The amount of RAP materials recycled within hot mix asphalt (HMA) drum plants are typically no more than 30% RAP. Asphalt pavement analyzer (APA) rutting, modified Lottman, and dynamic modulus testing were conducted on the RAP and virgin aggregate blended asphalt mixtures. On average between all RAP mixtures, the addition of RAP decreased rutting by 24%, and increased resilient modulus by 52% due to the addition of RAP asphalt binder and aggregates; which stiffen the mixture under higher temperature and heavier loading conditions. Dynamic modulus results indicated a statistical significant difference for high percentage RAP mixtures.

D. Production of innovative, recycled and high-performance asphalt for road pavements

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The paper deals with a specific laboratory study aiming at perfectioning recycled asphalt with high mechanical performance, for surface and structural layers of flexible pavements.
Theaimoftheresearchwastocombineinthesamematerialthemaximumpossiblequantityofrecycled asphalt (RA), coming from degraded asphalt layers, together with high structural performance of the recycled mixtures obtained (mainly stability, load spreading properties, rutting and fatigue resistance) that should not be lower, or possibly better than those offered by traditional asphalt mixture, made with virgin binder and aggregate.For this purpose, innovative recycled mixtures, close-graded and with high mechanical performance, characterized by high content of recycled asphalt (up to 50%) and designed for surface, binder and base layers were investigated in a laboratory study.
The results of physical and mechanical characterization tests show that,by controlling the homogeneity of recycled material and by using new bitumen with adequate rheological properties, it is possible to obtain paving mixtures with high content of recycled materials that, in relation to their intended use (surface, binder or base layer), can be considered as "high-performance mixtures".

E. Are totally recycled hot mix asphalts a sustainable alternative for road paving?

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The recycling of reclaimed asphalt pavement (RAP) helps road authorities to achieve their goal of a sustainable road transport system by reducing waste production and resources consumption. The environmental and economic benefits of using RAP in hot mix asphalt (HMA) applications could be pushed up to the limit, by producing totally recycled HMAs (100% RAP), but the performance of this alternative must be satisfactory. In fact, these mixtures could possibly present problems of workability and durability, higher binder aging and low fatigue cracking resistance. Thus, the objective of this study is to determine if totally recycled HMA mixtures could be a good solution for road paving, by evaluating the merit of some rejuvenator agents (commercial product; used engine oil) in improving the aged binders' properties and the recycled mixture performance. Several binder samples were prepared with the mentioned rejuvenators and characterized (Pen, R&B and dynamic viscosity), in order to select the best rejuvenator contents. The production temperatures of the corresponding recycled mixtures were evaluated based on their workability. Totally recycled HMAs were produced with the best previously observed combinations, and their performance (water sensitivity, rutting resistance, stiffness, fatigue resistance, binder aging) was assessed. The main conclusion of this study is that totally recycled HMAs can be a good

alternative for road paving, especially if rejuvenator agents are used to reduce their production temperature and to improve their performance.

F. Effects of moisture on strength and permanent deformation of foamed asphalt mix incorporating RAP materials

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Based on literature review on moisture susceptibility of hot-mixed asphalt and foamed asphalt (FA) mixes, a 24-h-soaking preconditioning method was selected to evaluate moisture effects on the strength and permanent deformation of FA mixes incorporating RAP materials in this study. Two grades of bitumen and two types of aged RAP materials were considered. Indirect tensile strength (ITS) test and dynamic creep test of FA mixes incorporating different RAP contents and stabilized by the two bitumens were tested under dry and soaked conditions. As well as ultimate strain, creep strain slope and secant creep stiffness modulus under two conditions were analyzed to evaluate moisture susceptibility of FA mixes in permanent deformation. Retained ITS results were evaluated to investigate moisture effect on property of indirect tensile strength of FA mixes. Bitumen grade and RAP content significantly affect ITS result of FA mixes, ITS will decrease with an increase of RAP content under both dry and soaked conditions. Bitumen grade and ageing of RAP material significantly affect moisture susceptibility of FA mixes in permanent deformation. Lower-grade bitumen and less aged RAP material help FA mixes to improve their moisture susceptibility in permanent deformation. 2006 Elsevier Ltd. All rights reserved.

G. Rutting Resistance of Asphalt Concrete Mixtures That Contain Recycled Asphalt Pavement

Alex K. Apeagyei, Brian K. Diefenderfer, and Stacey D. Diefenderfer

This study evaluated the rutting resistance of plant-produced asphalt concrete (AC) mixtures in the laboratory. Nineteen plant-produced AC mixtures were used; these mixtures contained reclaimed asphalt pavement (RAP) amounts that ranged from 0% to 25%. Tests on the mixtures included the dynamic modulus (E*) test at multiple temperatures and the flow number (FN) test at 54°C to characterize stiffness and rutting resistance, respectively. Mixtures that contained no RAP showed E* values comparable to those that contained 25% RAP in most cases. For most of the 19 mixtures tested, mixtures with lower FNs either contained no RAP, contained 25% RAP, or had PG 64-22 as the design binder grade. Mixtures that contained moderate amounts of RAP (10% and 15%), regardless of design binder grade, had higher FNs than mixtures with either high or low RAP amounts. Statistical analysis showed that the RAP amount was the most significant factor to affect rutting resistance in the mixtures studied. A linear inverse relationship between RAP and FN appeared to describe the data well. As the RAP amount increased, a downward trend occurred in both effective binder content (Pbe) and rutting parameter (G*/sin). The effect of RAP on FN was unexpected, because it showed the rutting resistance to decrease with increased RAP. Possible reasons might have been the use of softer asphalt binder in mixtures with higher RAP and the observed decrease in both Pbe and G*/sin with increased RAP amounts. More rutting-related mechanistic studies are needed of AC mixtures that contain RAP.

H. In Plant Production of Hot Recycled Mixtures with High Reclaimed Asphalt Pavement Content: A Performance Evaluation

Arianna Stimilli, Amedeo Virgili, Felice Giuliani and Francesco Canestrari

Nevertheless hot recycling process is nowadays a widespread technique, many doubts related to the in plant recycling process effects on the performance of recycled mixtures still exist and limit the maximum allowable amount of Reclaimed Asphalt Pavement (RAP). Therefore, the feasibility of an efficient

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production of plant hot recycled mixtures characterized by high RAP content and suitable performance should be properly addressed. To this aim, the overall performance of hot recycled asphalt mixtures produced in asphalt plant and containing high RAP content were assessed in this study. The mixtures were prepared with two different bitumens (high and low content of SBS polymer modifier) and 40 % of RAP only deriving from asphalt layers containing polymer modified bitumens. The aggregate grading curve was previously optimized through a specific laboratory study by applying the Bailey Method and using selected RAP. A third mixture, currently used for binder layers in motorway pavements, was also studied for comparative purposes. Compactability, stiffness, cracking and rutting resistance and fatigue behavior were investigated. Results of the mechanical tests suggest that mixtures containing 40 % RAP are suitable for the production of new asphalt pavements.

IV. Inference

- The 40% RAP mixtures demonstrates better compactability properties.
- The 40% RAP mixtures prepared with low modified bitumen was characterized by improved fracture properties. Rutting resistance of this mix was comparable with that of a reference mixture. It is confirmed that the 40% RAP mix can behave as well or even better than a reference mix if a low modified bitumen is used.
- Particular attention is focused on aggregate gradation and virgin bitumen type that can significantly alter the internal aggregate structure.
- Results show that as RAP percentage increased, dynamic modulus and resilient modulus decreased but the rutting resistance increased.
- Use of RAP in high modulus mixtures does not have negative effects on mechanical behaviour even when high percentage of RAP is used
- No significant differences were found in cracking behaviour, the recycled mix exhibited good resistance to moisture damage.
- Fatigue behaviour was also very much alike for all mixes especially with RAP percentages upto 30% with dynamic modulus values increasing with increasing RAP content, whereas the stiffness modulus and density of mixes tend to decline.
- Grade of bitumen and ageing of RAP material have significant impact on moisture susceptibility in permanent deformations. These also tend to increase the indirect tensile strength.
- In summary the recycling technology can be used to produce asphalt mixtures with performance as good as conventional HMA mixes, provided that adequate storing and handling conditions are assured during the production stage.

References

[1] "Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP)". Gonzalo Valdés a,b, Félix Pérez-Jiménez a, Rodrigo Miró a, Adriana Martínez a,⇑, Ramón Botella, Technical University of Catalonia, Jordi Girona 1-3, 08034, Barcelona, Spain b Universidad de La Frontera, Francisco Salazar 01145, Temuco, Chile

[2] "Evaluation of high modulus mixture behaviour with high reclaimed asphalt pavement (RAP) percentages for sustainable road construction". Rodrigo Miró a, Gonzalo Valdés a,b, Adriana Martínez a,⇑, Pilar Segura c, Celestino Rodríguez, Technical University of Catalonia, Barcelona 08034, Spain b Universidad de La Frontera, Temuco 4780000, Chile c Dragados (Grupo ACS), Madrid 28050, Spain d Asfaltos Augusta, Terrasa 08223, Spain

[3] "The determination of mechanical performance of laboratory produced hot mix asphalt mixtures using controlled RAP and virgin aggregate size fractions".Baron Colbert , Zhanping You Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, United States

[4] "Production of innovative, recycled and high-performance asphalt for road pavements". Clara Celauro*, Celauro Bernardo, Boscaino Gabriele. Dipartimento di Ingegneria delle Infrastrutture Viarie, Università degli Studi di Palermo, Viale delle Scienze, 90128 Palermo, Italy

[5] "Are totally recycled hot mix asphalts a sustainable alternative for road paving?" Hugo M.R.D. Silvaa,*, Joel R.M. Oliveiraa, Carlos M.G. Jesusb. C-TAC, Department of Civil Engineering, University of Minho, 4800-058 Guimarães, Portugal b Department of Civil Engineering, University of Minho, 4800-058 Guimarães, Portugal.

[6] "Effects of moisture on strength and permanent deformation of foamed asphalt mix incorporating RAP materials", He Gui-Ping a,b, Wong Wing-Gun, Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, PR China b Faculty of Highway Engineering, Changsha University of Science and Technology, Changsha, PR China. Received 12 January 2005; received in revised form 1 February 2006; accepted 30 June 2006, Available online 2 October 2006.

[7] "Rutting Resistance of Asphalt Concrete Mixtures That Contain Recycled Asphalt Pavemen"t, Alex K. Apeagyei, Brian K. Diefenderfer, and Stacey D. Diefenderfer

[8] "In Plant Production of Hot Recycled Mixtures with High Reclaimed Asphalt Pavement Content: A Performance Evaluation". Arianna Stimilli, Amedeo Virgili, Felice Giuliani and Francesco Canestrari.