CHARACTERIZATION AND DESIGN CRITERIA FOR RECYCLED WARM MIX IN PLANT - CASE STUDY

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Mix Design Criteria for Half Warm Asphalt Recycling (HWMR) - Case Study

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Abstract

Half warm mix asphalt recycling (HWMR) is a promising new technique for reclaimed asphalt pavement (RAP) recycling under development in Portugal. The technique is based in mix recycling RAP at low temperatures, between 70ºC and 100ºC. An attempt to apply this technique was made for the first time at EN 244 road, in the stretch between *Ponte de Sôr* and close to *Gavião*. The project was initially conceived by "*Direcção de Estradas de Portalegre*". The solution was found to be most appropriated for the rehabilitation of the existing asphalt pavement, both from the economical and environmental points of view. Although initially the mixing temperature was supposed to be between 70ºC and 100ºC, higher mixing temperatures were adopted later, during plant production, therefore Warm Mix Recycling (WMR) was used instead of HWMR..

This paper presents the preliminary results of a research project concerning design and performance of WMR / HWMR, using the mix asphalt recycling technique applied at EN244 road as a case study. The aim of this preliminary research work is to recommend design parameters for half warm mix asphalt recycling,. Tests were preformed using laboratory compacted specimens and specimens extracted directly from the

pavement in order to establish a mix design criteria (Marshall Stability, Immersion-compression test and Stiffness) and mix performance (Resistance to fatigue with four-point bending test on prismatic shaped specimens and Permanent deformation with Wheel Tracking).

Keywords: Bituminous pavements, Half warm mix recycling, Deformation, Fatigue.

1. INTRODUCTION

During their service life, asphalt pavements deteriorate, due to traffic and atmospheric actions, and when they reach their critical condition, rehabilitation is required. Removing the existing pavement and recycling it is one of the several alternatives available for pavement rehabilitation. Thus, reclaimed asphalt pavement (RAP) is commonly used in the production of (recycled) asphalt mixtures, replacing virgin mineral aggregates and bitumen, resulting in considerable savings of materials, money, and energy [1]. The percentage of RAP included in hot mix asphalt (recycled mix) depends on several factors, varying from 0 to about 30 percent for highway pavements, and may go as high as 60 percent for some applications [2]. Half warm mix asphalt recycling (HWMR) is a promising new technique to produce new asphalt mixtures using low mixing temperatures. By definition, half warm asphalt is produced with heated aggregate at a mixing temperature (of the mix) between approximately 70°C and 100°C, while warm mix asphalt is produced and mixed at temperatures roughly between 100 and 140°C [2].

Thus, HWMR consists in producing a new plant mixed, asphalt by heating RAP previously milled from the existing pavement, at temperatures between approximately 70°C and 100°C, and adding a small percentage of a bitumen emulsion (non heated). Then the mix obtained is placed again in the existing pavement to finalize the recycling process. By using this technique, 100% of RAP materials can be reutilized. The study of Warm Mix Recycling (WMR) / HWMR techniques is being carried out in CMADE (at Department of Civil Engineering at UBI) under the frame a PhD program study, with support fro LNEC.

Recently, WMR / HWMR was applied for the first time at EN 244 road, in the stretch between Ponte de Sôr and near Gavião village, in Portugal. The fact that existing pavement was already in an advanced deterioration state, having widespread and deep cracking was in the basis of the selection of this solution. Thus, recycling was thought to be more adequate since the rehabilitation of the existing pavement would involve milling a large percentage of its surface [3].

2. CASE STUDY

The pavement of EN244 road, built in 1987, was found to be in an advanced deterioration state, before the rehabilitation works. Pavement recycling was carried out in a total extension of about 24.2km, in the part between Ponte de Sôr and near Gavião village. The road is located in a typical rural area, having differentiated traffic, mainly rural motor vehicles.

Initial studies of the pavement condition concluded that a layer of 7cm depth of the existing pavement should be removed, by milling. This layer comprises the surface course (about 6cm) and part of the base course (of 1cm), according to the records of the original asphalt pavement structure [3].

Although there was an initial intention to use HWMR for this rehabilitation work, in practice, higher mixing temperatures (between 100ºC to 130ºC) were adopted for the mix production, in order to obtain a more homogeneous mixture and higher compaction in the final pavement.

Thus, recycling of existing pavement was carried out as follows:

1-removing of old asphalt by milling up to a depth of 7cm;

2-transportation and deposit of reclaimed asphalt pavement close to the asphalt mixing plant;

3- heating 100% RAP materials to temperatures 130ºC, approximately;

4- adding 2% of a bitumen emulsion (at ambient temperature,), by injection;

5- transporting, placing and compaction of the mixture at approximately 90ºC temperature.

3. MIX DESIGN CRITERIA FOR WMR / HWMR

3.1 RAP recovered bitumen and grading analysis

Several samples of RAP material were obtained during milling process and characterized in laboratory. Bitumen content was determined in laboratory by incineration. It was found to be between 4,8% and 5,3% of total RAP material. Grading analysis of RAP materials was carried out before and after bitumen extraction by incineration. The results obtained were compared with the grading requirements included in the standard specifications of the Portuguese Road Administration (“Estradas de Portugal” - EP requirements), as presented in Figure 1. The grading obtained for the RAP was compared with the requirements for recycled asphalt cold mixes (grading MR CE EP) and for asphalt hot mixes (grading MQ CE EP).

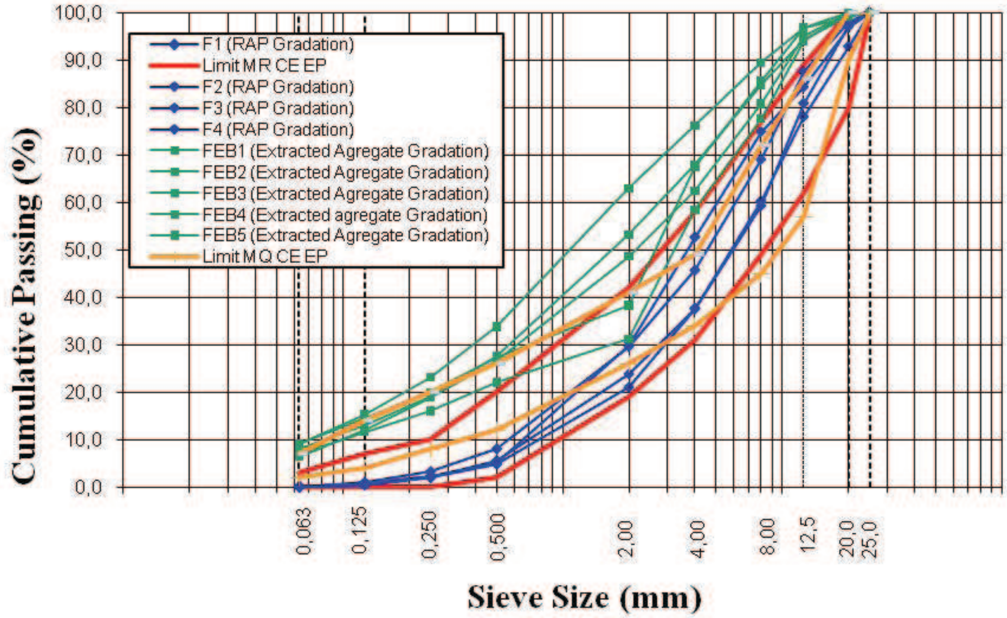


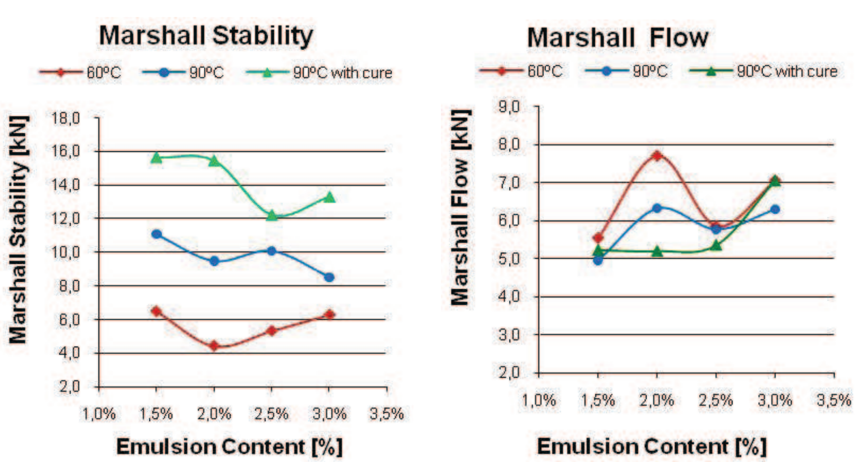
Fig.1. Grading analysis of RAP materials before and after bitumen extraction by burning

RAP gradings, as obtained from the pavement of this case study, were found out to comply with the recommended limits for cold recycled mixtures. However, the aggregates obtained after bitumen extraction, present finer gradings, outside the recommended limits for conventional asphalt mixtures. Indeed, compliance with grading requirements is one of the difficulties associated with the use of high RAP percentages in recycled mixtures.

3.2 Emulsion content

Half warm mix asphalt recycling (HWMR) can be considered, in terms of mixing temperatures, as being half way between hot and cold mix pavement technologies. Thus, which design methodology should be adopted? Is the methodology for cold mix design more adequate than the methodology for hot mix design? A methodology that combines cold and hot mix design criteria will be more adequate? Basically, the answers to these questions constitute the core of the research being carried out. In Portugal, design methodology for hot mixes is based in the Marshall method (using EN 12697-30 and EN 12697-34) while for cold mixes, immersion-compression tests (ASTM D 1075-96) is commonly used. Thus, as a starting point, both design methodologies were adopted to study a new design methodology for HWMR.

A large number of laboratory specimens were produced for both Marshall and immersion-compression tests. Specimens were prepared with mixes using different emulsion content (i.e. 1.5%, 2.0%, 2.5% e 3.0%), different mixing temperatures (RAP was heated up at 90ºC and 130ºC) and different compaction temperatures (60ºC and 90ºC, respectively for each mixing temperature) [5]. Specimens compacted at 60ºC were cured at room temperature for 24h. Part of the specimens compacted at 90ºC were cured at room temperature for 24h and another part was cured in the oven at 60ºC for the same curing period. Density was determined for each specimen, using the saturated surface dry (SSD) method. Results from Marshall test (average using five specimens) are presented in Figure 1, for different mixing and compaction temperatures.



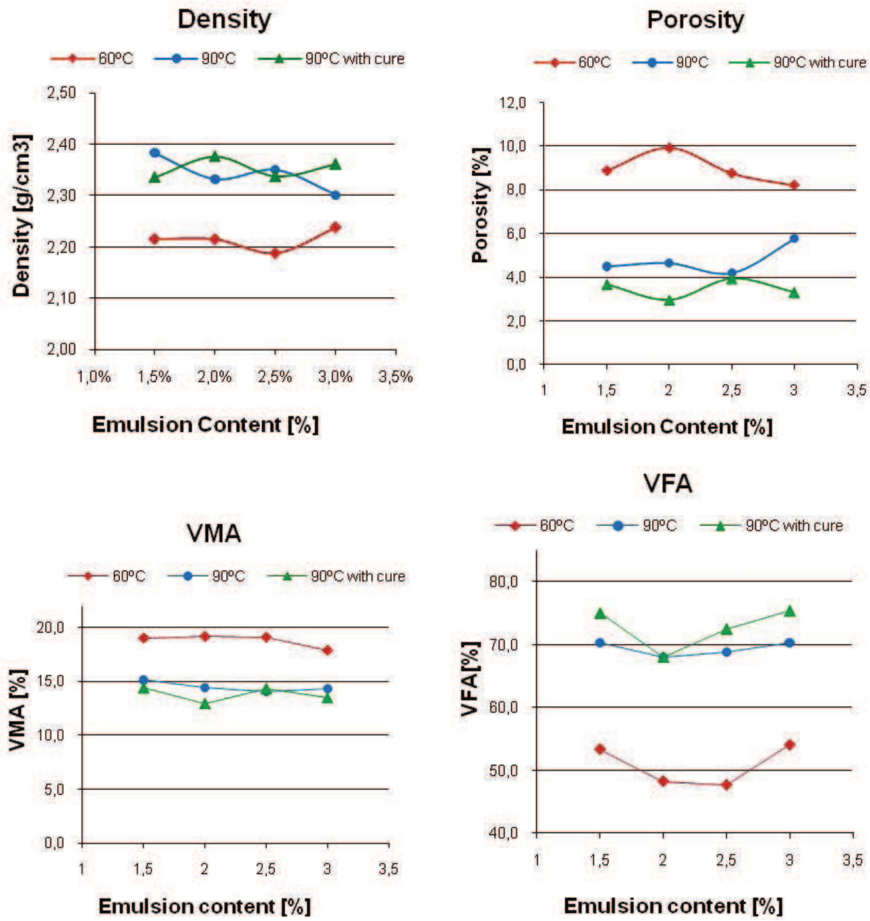


Fig.2. Marshall test results

Through the analysis of results obtained for different temperatures of compacting and curing, best results of Marshal test were found for mixes compacted at 90ºC followed by curing period in oven at 60ºC for 24h. Optimal adicional emulsion content was found to be between 2 to 2,5% of total RAP volume, taking into account the combination of maximum Marshall Stability, lower Marshall flow and higher density.

The results obtained in immersion-compression tests (average of five specimens) are presented in Table 1. By analysis of these results it can be observed that the retained strength is quite high (more than 90% in all cases, except for the mix having 3% emulsion content compacted at 60ºC). The results obtained are higher than EP requirements [4] (≥ 75% for "in situ" recycled mixes emulsion based, or ≥80% for asphalt hot mixes). The results of dry strength obtained for specimens compacted at 60ºC are not conclusive, since using 3% emulsion content gives lower values. However, for mixes compacted at 90ºC and cured either at room temperature or in the oven at 60ºC, it is verified that best retained strength results were obtained for 2% added emulsion content. Regarding density, it was verified that best results correspond, as well, to an added emulsion content of 2%.

Table 1 - Immersion-compression test results according to NLT 162/00

Emulsion	content (%)	Dry strength (kN)	Wet strength (kN)	Retained strength (%)	Density (g/cm3)
60ºC	1,5	33,481	30,574	91,31	2,27
	2,0	27,787	26,801	96,45	2,31
	2,5	24,737	23,415	94,65	2,28
	3,0	25,767	18,590	72,15	2,28
90ºC	1,5	36,717	36,125	98,39	2,34
	2,0	37,120	33,957	91,48	2,37
	2,5	34,700	32,810	94,55	2,34
	3,0	28,647	28,364	99,01	2,34
90ºC with 60ºC cure	1,5	37,544	33,716	89,80	2,30
	2,0	38,343	36,248	94,54	2,33
	2,5	38,490	35,351	91,85	2,33

	3,0	33,102	32,233	97,38	2,34

3.3 Stiffness Modulus

Determination of stiffness modulus was also carried on, according to EN 12697-26, applying repeated indirect tensile stress, as an additional optimization criterion for design of HWMR. To determine the stiffness modulus samples were compacted by double effect static compaction at 8MPa compressive stress, since the density results obtained for this stress value were found to be similar to the results obtained for in situ density, at EN 244. Stiffness modulus results are presented in figure 3, for each compaction temperature (60ºC and 90ºC) [6]. The results were obtained, along time, in samples cured at room temperature, for mixes having the same variables of those used in Marshall Stability and Immersion–compression tests.

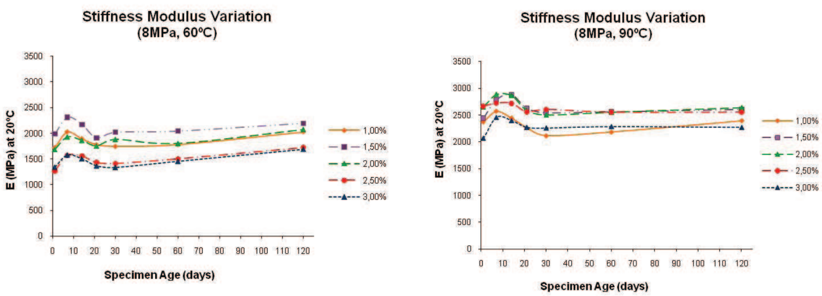


Fig.3. Stiffness modulus variation in time (compaction at 60ºC and 90ºC)

From the results obtained, it can be verified that stiffness modulus rises during the first week and then there is a decrease in stiffness, between 0 and 25 days. This occurs for any emulsion content and compaction temperature. Such behaviour might be explained by the presence of water emulsion in the specimens, during the first weeks. Obviously the mixing time and the RAP temperature were insufficient to fully evaporate emulsion water present in the mixtures, indicating that a curing period is necessary for HWMR technology. The increase of stiffness might be related with water suction (and not pore pressure), during the curing period.

4. CONCLUSIONS

Warm and half warm mix asphalt recycling (WMR / HWMR) is a promising recycling technique, since it enables savings of materials and energy and, consequently, environmental benefits.

The experience obtained in this case study of EN 244, indicates that RAP gradation, recovered bitumen content, mixing and compaction temperatures, as well as curing period, should be taken into account for mix design of WMR / HWMR.

Considering the results obtained using the Marshall mix design method, when compared to the methodology used for cold recycled mixtures used in Portugal, which us based in the immersion compression tests, it can be pointed out that Marshall formulation seems to be more adequate for mix design of WMR / HWMR: For the specific case of the mixture applied in the EN 244, specimen compaction at 90ºC and accelerated curing at 60ºC for 24 hours seems to be adequate.,.

REFERENCES

[1] Kandhal, P. e Mallick, R.: “Pavement Recycling Guidelines for State and Local Governments – Participant’s reference Book”. Federal Highway Administration, U.S. Departement of Transportation. Publication No. FHWA-SA-98-042, December, 1997.

[2] EAPA - European Asphalt Pavement Association: “The use of Warm Mix Asphalt” – Position Paper, June 2009.

[3] Soto, J.A.; Cardoso, A.J.M. e Vieira, L.: “Reciclagem Semiquente em Central. EN 244 – Entre Ponte de Sôr e o Entroncamento com a EN118 (Gavião)”. V Congresso Rodoviário Português “Estrada 2008”, Estoril, Portugal, 12-14 Março 2008.

[4] EP: “Caderno de Encargos Tipo Obra”, Capítulos 14.03 e 15.03 (Pavimentação). Estradas de Portugal, S.A., Fevereiro de 2009.

[5] Dinis de Almeida, M.; Castro Gomes, J.P. ; Antunes, M.L.: “Contributo para a formulação de misturas recicladas a semi-quente em central”. XV CILA – Congresso Ibero-Latino Americano do Asfalto, Lisboa, Portugal, 25-27 Novembro de 2009.

[6] Dinis de Almeida, M.; Castro Gomes, J.P. ; Antunes, M.L.: “Caracterização do Módulo de Rigidez de Misturas Recicladas a Semi-quente (100-140ºC) em Central”, Engenharia 2009 – Inovação e Desenvolvimento. Universidade da Beira Interior, Covilhã, 25-27 Novembro de 2009.