EVALUATION OF TWO LABORATORY-BASED DESIGN METHODS FOR CIR MIXTURES

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Abstract

In this laboratory research, two different methods for the design of cold in-place recycled (CIR) asphalt mixtures were compared. By the one hand, the current Spanish design method described in the Circular Order 40/2017 (current PG-4). By the other hand, the former Spanish design method described in the Circular Order 8/2001 (former PG-4). Both design methods specify different compaction mechanisms (static vs gyratory), water sensitivity test (unconfined compression strength ratio vs indirect tensile strength ratio) and different ways to obtain the added water for the samples.

In order to compare both design methods, CIR samples were manufactured following both design procedures. A cationic slow setting bitumen emulsion C60B5REC was used as binder. Residual binder contents ranging from 1.5% to 5.25% were tested. Added water contents ranging from 0% to 2.75% were also tested. CIR mixtures manufactured according with the former PG-4 led to an optimum residual binder content of 2.00%. Nevertheless, it was not possible to manufacture a CIR mixture that met all the current PG-4 specifications. In this sense, despite in this last case were used higher residual binder contents, 1% of Portland cement as filler, different water contents and higher compaction energy. In this regard, the indirect tensile strength ratio was achieved, but it was impossible to achieve the dry and wet indirect tensile strength requirements.

Keywords: cold in-place recycled (CIR) asphalt mixture; reclaimed asphalt pavement (RAP); bituminous emulsion; design method; gyratory compactor.

1. Introduction

Cold in place recycled (CIR) asphalt mixture are composed of reclaimed asphalt pavements (RAP) and natural aggregates bonded with bitumen emulsion or foam bitumen [1]. Also, active fillers, such as cement, could be added in order to improve the performance of CIR mixtures [1].

Worldwide, scientific literature shows that pavement recycling and rehabilitation existed since the beginning of the XX century, but it is not until mid-1970s when modern CIR (Cold in place recycling) specialized equipment and techniques started to be used [2, 3]. However, despite the fact that CIR is being used for many years, there are still some technical problems to be concerned about, such us mix design, execution, laboratory testing methods, etc. and this is the reason why there is not just one single regulation for this type of mixtures. Rather than an unique standard, each location develops different guidelines and recommendations [4-8]. Also, many companies in pavement recycling sector have developed their own manuals [9].

Particularly in Spain, it is applicable the Circular Order 40/2017 (known as PG-4) [10] that substitutes the Circular Order 8/2001 (former PG-4) [11], both of them about Pavement Recycling, with new specifications for the design and evaluation of CIR, including construction techniques as well as laboratory manufacturing, curing and testing procedure. This change in compaction and demanded testing strength is leading to difficulties with the dosage of the mixes in order to comply with new requested requirements, which would be exposed and compared in this investigation.

2. Materials and methods

2.1. Materials

2.1.1. RAP

100% RAP CIR mixtures have been tested. A local contractor supplied the RAP. As can be see in figure 1, the sieve size distribution corresponds to a granulometric splinde RE1 according to the old PG-4 [11] and to a RE2 according to the current PG-4 [10].

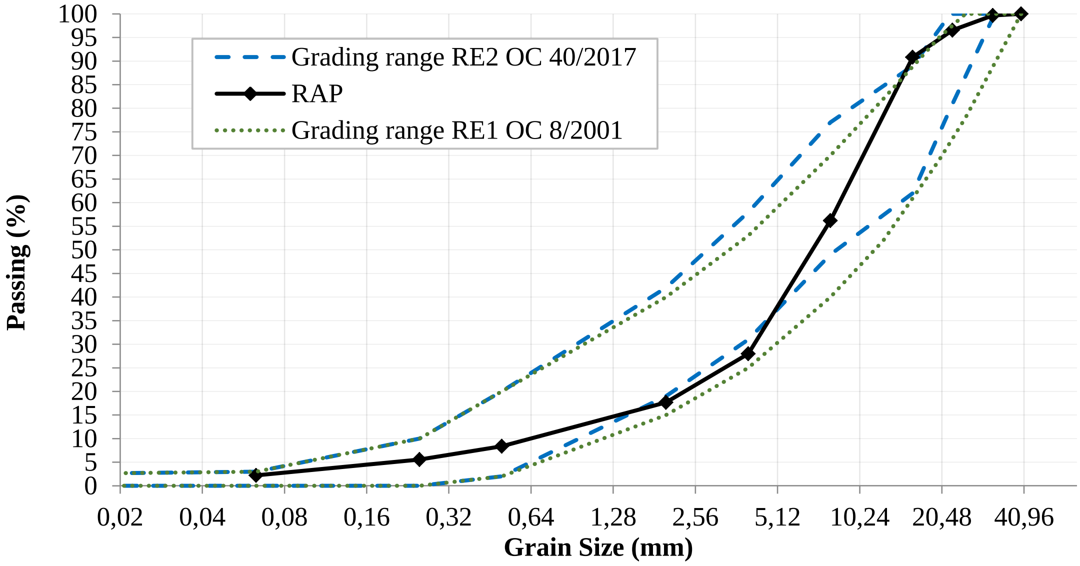

FIGURE 1 – RAP GRADATION COMPARED WITH BOTH PG-4 SPECIFICATIONS

The bulk specific density of the RAP, obtained according to EN 1097-6 [12], is 2.56 g/cm^3 and the residual binder content is 7.81%, obtained according to the Spanish Standard NLT-164/90 [13].

2.1.2. Bitumen emulsion

The bitumen emulsion used was a C60B5 REC, which corresponds to a cationic slow-setting emulsion with 60% bitumen content and 100-pen grade bitumen.

2.1.3. Portland cement

Grey Portland cement (CEM II/B-M (V-L) 32.5 N), was used as active mineral filler in one of the studied mix series.

Its specific gravity was equal to 3.10 g/cm^3.

2.2. Methods

2.2.1. Modified Proctor test

In order to obtain the optimum moisture content of the mixes studied, Modified Proctor test were conducted according to the EN 103501 [14]. The RAP was heated at 60°C during 24h in order to dry it completely, and once it returns to room temperature (20°C), RAP is divided in six separated samples and mixed with different amounts of water, in order to obtain different moisture content blends. Dry density of the samples are obtained so as to estimate the optimum moisture content (MPT) for which the calculated density value is the maximum.

2.2.2. Immersion-Compression Test

This test was performed according to the Spanish Standard NLT-162 [15] to verify the minimum resistance values of former PG-4 [11], shown below (Table 1).

Heavy traffic categories	Dry (MPa)	After immersion (MPa)	Preserved (%)
T1 (base) and T2	3	2.5	75
T3, T4 and shoulders	2.5	2	70

TABLE 1 - MINIMUM RESISTANCE VALUES IN IMMERSION-COMPRESSION TEST ACCORDING TO THE FORMER PG-4

Five different groups of ten cylindrical specimens of 101.6 mm diameter x 101.6 mm height were manufactured using different bitumen emulsion contents, in order to estimate the optimum dosage.

2.2.3. Gyratory compaction Test

This compaction method was performed according to EN 12697-31 [16]. The current PG-4 [10] indicates that CIR laboratory specimens should be compacted with this procedure, using 100-150 gyration depending on the granulometric spindle and the diameter of the specimens (100 or 150mm). For this study, the employed diameter is 100mm.

2.2.4. Water Sensitivity Test (Indirect tensile strength)

Water sensitivity tests were conducted following the indications of EN 12697-12 [17]. The current PG-4 [10] strength requirements are not based on immersion-compression tests as it used to be in former normative [11], but based on indirect tensile strength for the dry (ITSd) and wet (ITSw) subsets and on the indirect tensile strength ratio (ITSR) values, as shown in table 2.

Heavy traffic categories (*)	ITSd (MPa)	ITSw (MPa)	ITSR (%)
T1 (base) and T2	1.7	1.3	75
T3, T4 and shoulders	1.2	0.9	70

Traffic category T00 refers to AADHT (Annual Average Daily Heavy Traffic)≥4,000
Traffic category T0 refers to 4,000>AADHT ≥2,000
Traffic category T1 refers to 2,000>AADHT ≥800
Traffic category T2 refers to 800> AADHT ≥200
Traffic category T3 refers to 200>AADHT ≥50
Traffic category T4 refers to AADHT<50

TABLE 2 - MINIMUM RESISTANCE VALUES IN INDIRECT TENSILE STRENGTH TEST ACCORDING TO THE CURRENT PG-4

Different mix series of cylindrical specimens of 100 mm diameter x 65 (±2) mm (in order to fit correctly in the indirect tensile machine), compacted with 100, 150 or 200 gyrations of gyratory compactor, were done in order to analyse the affection of these parameters in the design. For four of the mix series, different bitumen emulsion and water content were analysed. And additionally, one more serie of 100 gyrations with 1% of added Portland cement was studied too.

2.2.5. CIR manufacturing

The manufacturing process was carried out according to parameters in table 3.

<table>
<tr><th>Series Name</th><th>Standard</th><th>Design Method</th><th>Compaction Method</th><th>Residual Bitumen</th><th>OWC</th><th>Portland Cement</th></tr>
<tr><td>Static series</td><td>CO 8/2001</td><td>Dry and wet Unconfined Compression Strength (UCSd and UCSw)

Retained Strength Ratio (RSR)

(NLT-162)</td><td>Static compaction</td><td>1.50%
1.75%
2.00%
2.25%
2.50%</td><td>2.75%
2.33%
1.92%
1.50%
1.08%</td><td rowspan="4">0.00%</td></tr>
<tr><td>Gyratory series 1</td><td>CO 40/2017</td><td rowspan="5">Dry and wet Indirect Tensile Strength (ITSd and ITSw)

Indirect Tensile Strength Ratio (ITSR)

(EN 12697-12)</td><td rowspan="2">Gyratory compactor (100 gyr.)</td><td>2.50%
3.00%
3.50%
4.00%
5.25%</td><td>2.75%
2.25%
1.75%
1.25%
0.00%</td></tr>
<tr><td>Gyratory series 2</td><td rowspan="4">CO 40/2017*</td><td rowspan="3">1.50%
2.00%
2.50%
3.00%</td><td rowspan="3">2.75%
1.92%
1.08%
0.25%</td></tr>
<tr><td>Gyratory series 3</td><td>Gyratory compactor (150 gyr.)</td></tr>
<tr><td>Gyratory series 4</td><td>Gyratory compactor (200 gyr.)</td></tr>
<tr><td>Gyratory series 5</td><td>Gyratory compactor (100 gyr.)</td><td>1.50%
2.00%
2.50%
3.00%</td><td>5.00%
4.17%
3.33%
2.50%</td><td>1.00%</td></tr>
</table>

TABLE 3. PARAMETERS OF SAMPLES SERIES

3. Results and discussion

3.1. Modified Proctor Test

As can be seen in figure 2, the results of the modified Proctor test performed with 100% of RAP showed a maximum dry density of 1.94 g/cm^3 for an optimum water content of 5.75%. Figure 2, also shows that in the case of adding an additional 1% of Portland cement to RAP, dry density ascend to 2.00 g/cm^3 for an optimum water content of 8.00%.

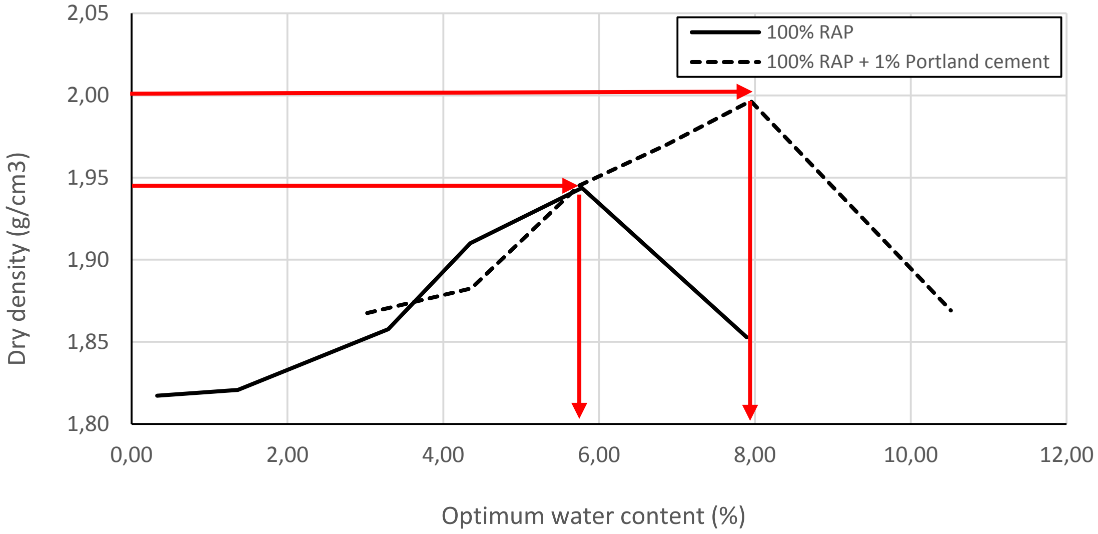

FIGURE 2 - MODIFIED PROCTOR TEST RESULTS

3.2. Immersion-compression Test

As can be seen in figure 3 the retained strength ratio (RSR) for all the residual binder content tested is higher than minimum requirements specified in the former PG-4 [11]. However, the unconfined compression strength (UCS) dry and wet values only satisfy the traffic categories “T3, T4 and shoulders” for 2.00% and 2.25% of residual binder. That is the reason why the optimum residual binder content selected according to this Standard method is 2.00%.

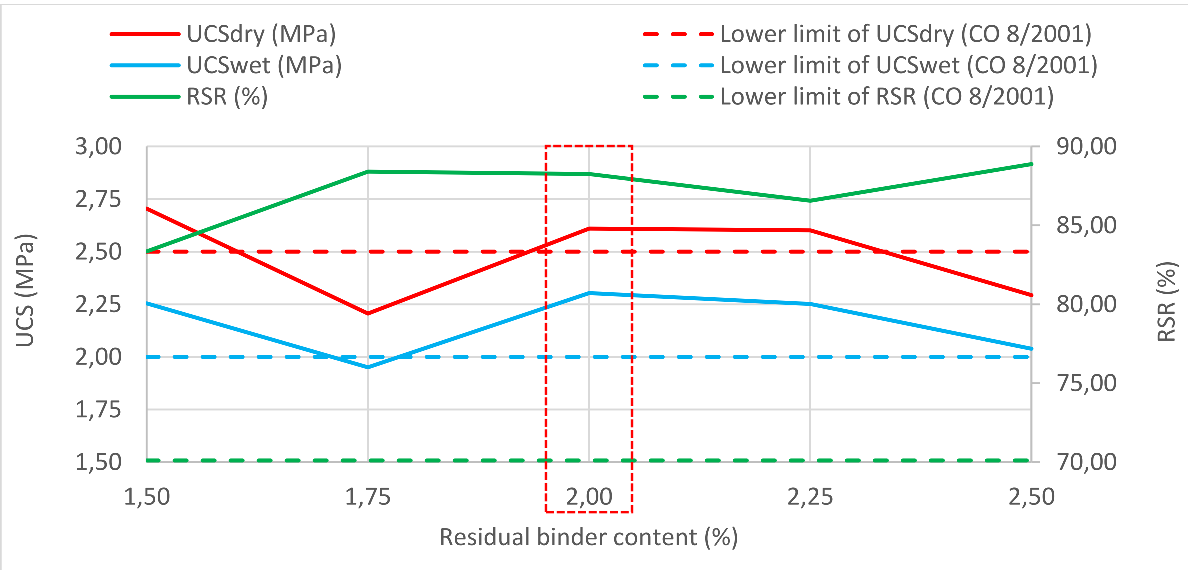

FIGURE 3 – IMMERSION-COMPRESSION RESULTS

3.3. Water Sensitivity Test (Indirect tensile strength)

As is shown in figure 4, despite the fact that ITSR values are satisfactory in all cases (figure 4a), indirect tensile strength values are not achieved, neither dry (figure 4b) nor wet (figure 4c) specimen group. In contrast to the results obtained with the method from previous PG-4 [11], this time, following the specimen fabrication method from current PG-4 [10], requested resistance values were not achieved.

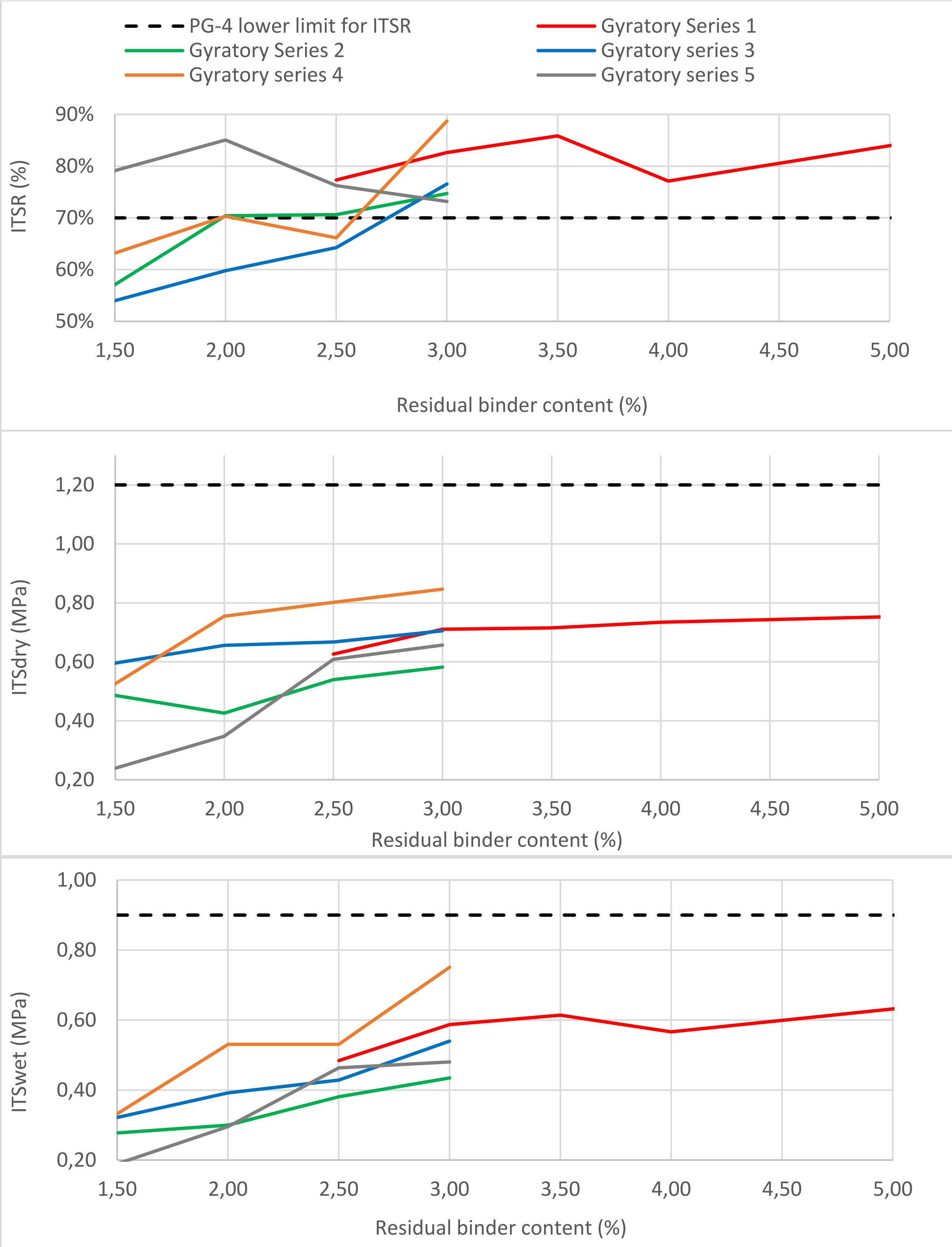

FIGURE 4 - WATER SENSITIVITY TEST RESULTS: A) ITSR, B) ITSDRY AND C) ITSWET

4. Conclusions

As can be noticed, from this research, we can conclude that the current PG-4 specifications are very restrictive:

- Using the optimum binder content and added water of the former PG-4, the requirements of the current PG-4 are not achieved by far, particularly for the ITS values.
- Using 1% of Portland cement as active filler, compacting with a higher number of gyrations (from 100 to 150 and 200), increasing the residual binder content (from 1.5% to 3.0%) and changing the water content , the ITS values increase, but the values are still not high enough to meet requirements from current PG-4.

In view of the exigency level from currently in force specifications, it is considered necessary a revision of the requested values of ITSdry and ITSwet and further investigation is needed in order to stablish these lower required limits.

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