Cold Recycled Asphalt Bases

for Optimised Energy & Resource Efficient Pavements

CRAB for OERE

Instrumented road section – Republic of San Marino

1 Introduction

The Azienda Autonoma di Stato per i Lavori Pubblici AASLP (San Marino state-owned enterprise for public works) and the University of the Republic of San Marino (UniRSM) collaborate since 2016 for the maintenance management of the State road network (Figure 1). In the sector of road construction and maintenance, the relationship between the two national institutions has been continually strengthened so far for research purposes and direct application in field.

AASLP is extremely devoted to enhancing the knowledge on cold recycling and to use as much as possible this technology in place of the traditional one. For these reasons, AASLP, in collaboration with UniRSM, decided to support the design and construction of a trial section to be included in the 2020 road maintenance project and to collaborate with the research consortium CRABforOERE for introducing sensors, taking samples and performing measurements on the demonstration structure.

Figure 1. Federico Bartoletti (AASLP president), Corrado Petrocelli (UniRSM Rector), Matteo Casali (AASLP Director), Andrea Grilli (Associate Professor UniRSM)

One of the main objectives of AASLP is to reduce the environmental impact and to pursuit sustainable construction. Road construction and maintenance involve huge amounts of materials including waste materials from the milling or demolition of asphalt pavements. Traditionally, reclaimed asphalt (RA) has been used into new hot mix asphalt (HMA). However, technical difficulties or facility issues limit the integration of HMA with RA and a large amount of RA remains often unused in stockpile areas. On the other hand, cold recycling can really maximize the amount of RA to be recycled without penalizing the mechanical characteristics of the final product. Certainly, cold recycling allows the highest environmental and economic benefits to be achieved by reducing the consumption of manufacture energy, production emissions and natural resources.

Over the years, the collaboration between AASLP and UniRSM has led to the organization of numerous meetings and workshops as well as the establishment of relationship with Italian municipalities and Universities. Some experiences on the application of cold in-plant recycling in San Marino have been published in *Grilli A., Mignini C. And Graziani A. "Field behaviour of cold-recycled asphalt mixtures for binder courses", Sustainable Materials, Systems and Structures, RILEM spring conference, Rovinj, Croatia, 18-22 March 2019* and the topic still stimulates further research and a wider implementation.

2 Maintenance working plan

The trial section is located on the road *XXV Marzo* (Republic of San Marino). The road is a two-lane dual carriageway facility and is part of the main connector that links San Marino historic centre to the Adriatic coast (Figure 2) with an average daily traffic of about 4.000 vehicles.

Figure 2. Location of the trial section (via XXV Marzo, Republic of San Marino)

The working yard is divided into four subsections and three maintenance methods have been provided as showed in Figure 3. CRABforOERE sensors installation and sampling activities to monitor the properties evolution of the cold recycled mixture are undertaken on subsection 2 and 3. However, a proper description of the overall working plan is needed to have a thorough understanding on the management and development of the mix-plant and technical activities.

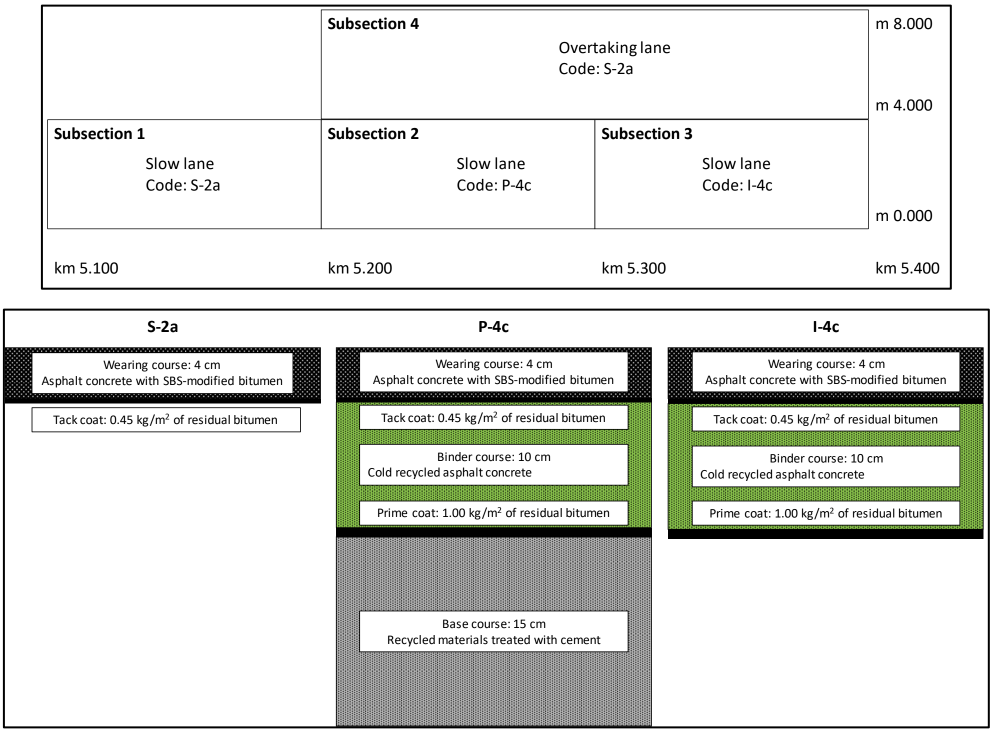

Figure 3. Scheme of the working sections and maintenance methods

The four subsections are characterized by different pavements distresses:

- the dominant distress in the subsection 1 (slow lane, about 400 m^2 from km 5.100 to km 5.200) is displacement of asphalt concrete, so called shoving, in a localized area of the pavement surface caused by traffic loading, particularly tangential stresses, and unstable asphalt concrete (Figure 4). The maintenance of subsection 1 requires the milling of 4 cm of the old pavement, mechanical brooms for sweeping loose material from the surface prior to placing the tack coat (bituminous emulsion with dosage of 0.45 kg/m^2 of residual bitumen and saturation with mineral filler) and laying and compaction of 4 cm of asphalt concrete (maintenance work code: S-2a);

- subsection 2 showed a series of interconnecting cracks caused by repeated traffic loading, high-severity level of the fatigue cracking, combined with a localised depression due to the settlement of the foundation (Figure 5). The maintenance of subsection 2 requires the milling of 29 cm of the old pavement, laying and compaction of 15 cm of cement treated recycled materials, spreading of the prime coat (bituminous emulsion with dosage of 1.00 kg/m^2 of residual bitumen and saturation with mineral filler), laying and compaction of 10 cm of cold recycled mixture, spreading of the tack coat (bituminous emulsion with dosage of 0.45 kg/m^2 of residual bitumen and saturation with mineral filler) and laying and compaction of 4 cm of asphalt concrete (maintenance work code: P-4c);
- subsection 3 showed medium-severity level of the fatigue cracking (Figure 6). The maintenance of subsection 3 requires the milling of 14 cm of the old pavement, spreading of the prime coat (bituminous emulsion with dosage of 1.00 kg/m^2 of residual bitumen and saturation with mineral filler), laying and compaction of 10 cm of cold recycled mixture, spreading of the tack coat (bituminous emulsion with dosage of 0.45 kg/m^2 of residual bitumen and saturation with mineral filler) and laying and compaction of 4 cm of asphalt concrete (maintenance work code: I-4c);
- the dominant distress in subsection 4 is a series of cracks extended across the pavement at approximately right angles to the pavement centreline, medium-severity transverse cracking, and longitudinal cracking on paving lane joint (Figure 7). The maintenance of subsection 4 requires the milling of 4 cm of the old pavement, mechanical brooms for sweeping loose material from the surface prior to placing the tack coat (bituminous emulsion with dosage of 0.45 kg/m^2 of residual bitumen and saturation with mineral filler) and laying and compaction of 4 cm of asphalt concrete (maintenance work code: S-2a).

Figure 4. From km 5.100 to km 5.200, slow lane

Figure 5. From km 5.200 to km 5.300, slow lane

Figure 6. From km 5.300 to km 5.400, slow lane

Figure 7. From km 5.200 to km 5.400, overtaking lane

A campaign of IRI measurements was performed on both, slow and overtaking lanes. Figure 8 and Figure 9 show the IRI average values coming from three measurement repetitions on the slow lane and overtaking lane, respectively [Balzi et al., 2019].

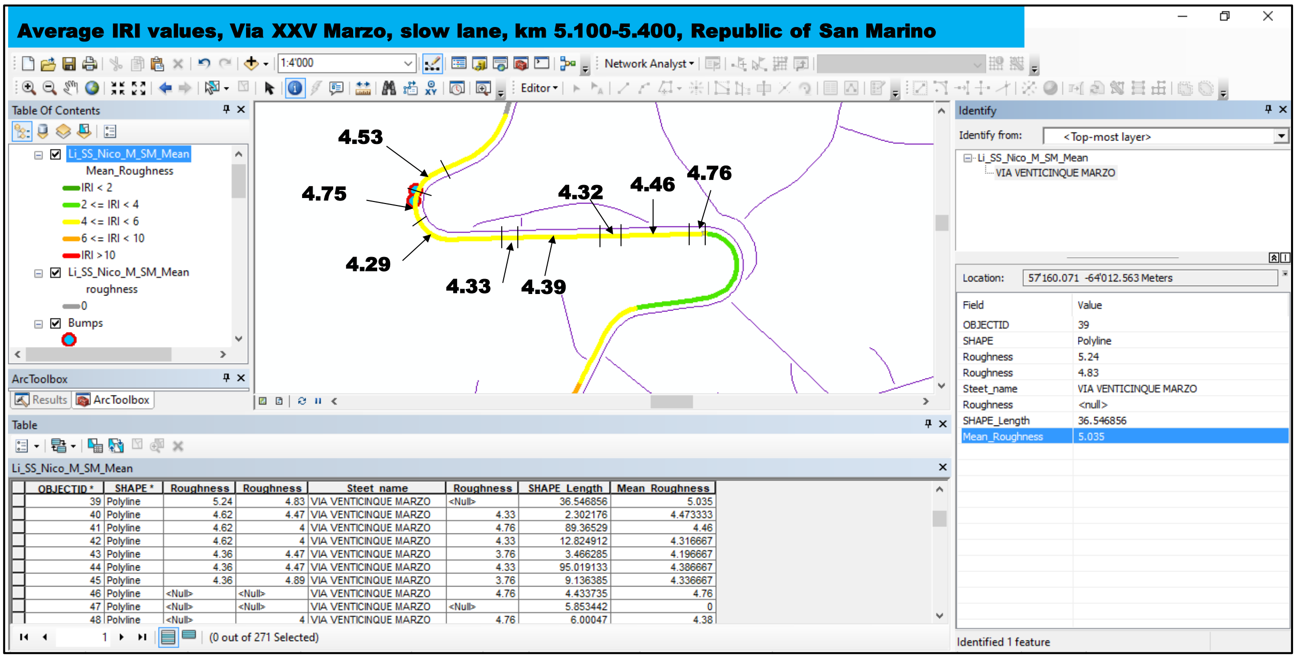

Figure 8. Mean IRI values on the slow lane using GIS tools

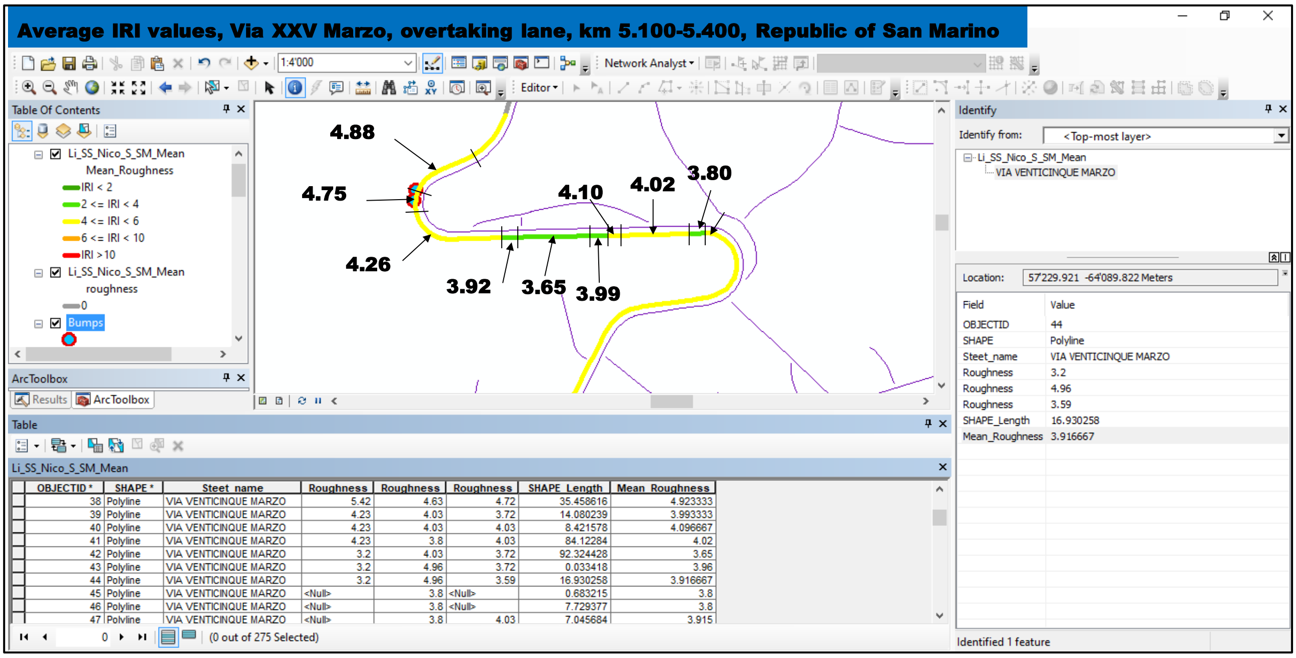

Figure 9. Mean IRI values on the overtaking lane using GIS tools

3 Materials specifications

The following tables are extracted from the AASLP construction specification [AASLP, 2020].

3.1 Asphalt concrete for wearing course:

Table 1. Coarse aggregate characteristics (D ≤ 45 mm; d ≥ 2 mm), at least 40% by aggregate weight

Parameter	Standard	Unit	Requirement	Class EN 13043
Resistance to fragmentation	EN 1097-2	[%]	≤ 20	LA_{20}
Percentage of crushed and broken surfaces	EN 933-5	[%]	100	$C_{100/0}$
Passing at 0,063 mm	EN 933-1	[%]	≤ 2	f_2
Resistance to freezing and thawing	EN 1367-1	[%]	≤ 1	F_1
Flakiness index	EN 933-3	[%]	≤ 15	FI_{15}
Shape index	EN 933-4	[%]	≤ 15	SI_{15}
Polished stone value	EN 1097-8	[-]	≥ 50	PSV_{50}
Water absorption	EN 1097-6	[%]	≤ 2	$WA_{24}2$

Table 2. SBS-modified bitumen characteristics

Bitumen designation EN 14023			PmB 45/80-70	
Parameter	**Standard**	**Unit**	**Requirement**	**Class**
Needle penetration at 25°C	EN 1426	[× 0.1 mm]	45 - 80	4
Softening point	EN 1427	[°C]	≥ 70	4
Fraass breaking point	EN 12593	[°C]	≤ - 12	6
Dynamic viscosity at 180°C	EN 13302	[mPa · s]	50 - 200	-
Elastic recovery at 25° C	EN 13398	[%]	≥ 80	2
Storage stability (∆ pen)	EN 133399	[× 0.1 mm]	9	2
Storage stability (∆ R&B)	EN 133399	[°C]	5	2
Resistance to hardening RTFOT	EN 12607-1			
Change in mass	EN 12607-1	[%]	≤ 0.5	3
Retained penetration at 25°C	EN 1426	[%]	≥ 60	7
Change in ring and ball softening point	EN 1427	[°C]	≤ 8	2

Table 3. Grading envelope and bitumen content range of the asphalt concrete for wearing course

Asphalt concrete designation	AC12
Sieve size [mm]	**Passing material [%]**
20	100
12,5	90 - 100
8	72 - 84
4	44 - 55
2	26 - 36
0,5	14 - 20
0,25	10 - 15
0,063	6.0 – 10.0
Bitumen content	
Bitumen content by mix weight [%]	4.7 – 5.8
Bitumen content by aggregate weight [%]	4.9 – 6.2
Bitumen content values have to be corrected by the factor: $a = 2.650/\rho_a$. Where ρ_a is the particle density [in Mg/m^3] following the procedure EN 1097-6.	

Table 4. Volumetric and mechanical requirements of the asphalt concrete for wearing course

Compaction method			
Parameter	**Unit**	**Standard**	**Requirement**
External angle	[°]	SHRP Designation M-002	1.25 ± 0.02
Speed of rotation	[revolution/min]	EN 12697-31	30
Consolidation pressure	[kPa]	EN 12697-31	600
Mould diameter	[mm]	EN 12697-31	100
Compaction temperature	[°C]	EN 12697-35	Operative temperature ± 10
Volumetric and mechanical properties			
Parameter	**Unit**	**Standard**	**Requirement**
V_m at 10 revolutions (N_1)	[%]	EN 12697-8	11 - 15
V_m at 100 revolutions (N_2)	[%]	EN 12697-8	3 - 6
VMA at 100 revolutions (N_2)	[%]	EN 12697-8	> 12
VFB at 100 revolutions (N_2)	[%]	EN 12697-8	65 - 80
V_m at 180 revolutions (N_3)	[%]	EN 12697-8	> 2
Indirect tensile strength 25°C at N_2 (*ITS*)	[N/mm^2]	EN 12697-23	0.95 – 1.80
Water sensitivity (*ITSR*)	[%]	EN 12697-12	≥ 90

3.2 Cold recycled mixture for binder course

Table 5. Modified bituminous emulsion for cold in plant recycling

Modified bituminous emulsion				
Parameter	**Standard**	**Unit**	**Requirement**	**Class EN 13808**
Polarity	EN 1430	-	positiva	2
Bitumen content	EN 1428	[%]	60 ± 2	
Settling tendency at 7 days	EN 12847	[%]	≤ 10	3
Breaking value	EN 13075-1	-	> 150	5 or upper
Mixing stability with cement	EN 12848	[g]	< 2	10
Residual bitumen				
Needle penetration at 25°C	EN1426	[0,1 × mm]	< 100	3
Softening point	EN1427	[°C]	> 55	2
Cohesion at 10°C	EN 13589 EN 13703	J/cm^2	≥ 2	6
Elastic recovery	EN 13398	[%]	> 50	3

Table 6. Grading envelope of the cold recycled blend for binder course

Asphalt concrete class	**AC20**
Sieve size [mm]	**Passing material [%]**
31.5	100
20	90 - 100
10	50 - 80
4	30 - 55
2	20 - 40
0.5	10 - 25
0.063	3.0 – 8.0

Table 7. Composition and mechanical requirements of the asphalt concrete for wearing course

Compaction method			
Parameter	**Unit**	**Standard**	**Requirement**
External angle	[°]	SHRP Designation M-002	1.25 ± 0.02
Speed of rotation	[revolutions/min]	EN 12697-31	30
Consolidation pressure	[kPa]	EN 12697-31	600
Energy	[revolutions]	EN 12697-31	100
Mould diameter	[mm]	EN 12697-31	150
Mould type	-	-	closed
Wet sample	[g]	-	2800
Maximum size	[mm]	-	20
Optimum water content			
Cement content	[% by aggregate weight]	2	maximum dry density and lea-king water < 0.5%
Water content	[% by aggregate weight]	3, 4, 5, 6	
Optimum binders content			
Water content	[% by aggregate weight]	optimum	ITS ≥ 0.40 MPa; ITSR ≥ 80 %; ITSM ≥ 3000 MPa
cement content[1]	[% by aggregate weight]	1.5; 2.0 e 2.5	
Emulsion content[1]	[% by aggregate weight]	4.0; 4.5 e 5.0	
[1] only the combinations that allow a bitumen/cement ratio > 1			

3.3 Cement treated materials for base course

Table 8. Grading envelope of the cement treated materials for base course

Sieve size [mm]	**Passing material [%]**
40	100
31.5	85 - 100
20	65 - 94
10	44 – 78
2	18 - 50
0.5	8 - 30
0.25	6 - 22
0.063	3.0 – 11.0
CBR index after 4-day soaking (EN 13286-47)	> 50
Vertical swelling after 4-day soaking (EN 13286-47)	0

Compaction method			
Parameter	**Unit**	**Standard**	**Requirements**
Energy Proctor	[MJ/m^3]	EN 13286-2	2.7 (modified)
Mould diameter	[mm]	EN 13286-2	150
Layers	[n]	EN 13286-2	5
Thickness	[mm]	EN 13286-2	120 (optimum water and R_{it}) 180 CBR mould (R_c)
Blow per layer	[n]	EN 13286-2	56 (optimum water and R_{it}) 85 (R_c)
Optimum water content			
Cement content	[% by aggregate weight]	4	Dry maximum density $\rho_{d,max}$
Water content	[% by aggregate weight]	4, 5, 6 e 7	
Optimum cement content			
Water content	[% by aggregate weight]	optimum	$R_{it} \geq 0.25$ N/mm^2; $R_c = 2.5 - 5.0$ N/mm^2
Cement content	[% by aggregate weight]	3, 4, 5	

4 Mix design of cold recycled mixture

In a previous study the mix design of the cold recycled mixture for binder course established the following recipe: 4.5% of bitumen emulsion (2.7% of residual bitumen), 2% of cement and 5% of water by aggregate weight (including water brought in by emulsion). According to the specification of the San Marino road agency, this recipe allowed obtaining an indirect tensile strength at 25 °C of 0.41 N/mm^2 (curing period of 72 hours at 40 °C) and a dry density of 2123 kg/m^3 [Grilli et al., 2019].

References

Azienda Autonoma di Stato per i Lavori Pubblici AASLP "Capitolato Speciale d'Appalto per la Manutenzione Straordinaria per Opere Stradali", Edition 2020.

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