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ECO-SUSTAINABLE SOLUTIONS FOR THE MAINTENANCE OF THE ROAD PAVEMENTS IN THE REPUBLIC OF SAN MARINO

Andrea Grilli[1], Alex Balzi[1], Arianna Ciotti[1], Matteo Casali[2], Raoul Chiaruzzi[3]
[1] *University of the Republic of San Marino, Republic of San Marino*
[2] *Professional Engineer, Republic of San Marino*
[3] *Azienda Autonoma di Stato per i Servizi Pubblici, Republic of San Marino*

Abstract

In the last decade, climatic changes have caused intense natural phenomena such as heavy precipitations, dry and hot weather, river flood waves, sea level increase and fluctuations that impact on the social life, significantly. All over the world, governments are now asked to stimulate and to adopt new tools to preserve natural resources and to reduce atmospheric pollutions. Therefore, new complex aspects have to be considered also in management and maintenance of road network matching policies, investment strategies and engineered solutions. Since 2016, the San Marino state-owned enterprises for public works (Azienda Autonoma di Stato per i Lavori Pubblici) and for public utilities (Azienda Autonoma di Stato per i Servizi Pubblici), in collaboration with the University of the Republic of San Marino, have gradually introduced eco-sustainable techniques for the maintenance of road pavements and utility trenches, involving local construction enterprises and mix plants. This paper describes the approach and the specifications for eco-sustainable road materials such as cold and hot recycled asphalt concrete, cement treated recycled materials and cold surface treatments. These materials are used in San Marino for road pavements and in the utility trenching.

Keywords: cold techniques, recycling, bituminous emulsion, surface treatments

1 Introduction

The construction and maintenance of road pavements involve several technical, economic and environmental issues, such as methodologies to be adopted, selection of materials, operative costs and associated impacts on natural resources. Although eco-friendly techniques hold certain benefits over conventional construction techniques, their implementation in road maintenance projects seems to be hindered by scepticism among technicians and professional engineers which is mainly due to the lack of well-established knowledge and design documentations.

Particularly, best practices on environmentally friendly techniques have to be transferred, accessible and manageable by local administrations which generally have few resources for upgrading their standards to new methods. At the same time, they manage most of the road pavement network of the country.

This article describes the prospects and the importance of implementing eco-sustainable techniques such as recycling and cold techniques and gives some key information for local road administrations. A gradual integration of eco-sustainable techniques in the planning and design of road pavements was undertaken to stimulate and to pursuit the circular economy of the Republic of San Marino. This paper deals with the general concepts behind the adopted standards which addressed to the implementation of several eco-sustainable techniques through tailored specifications [1] and an easy-to-use structural design catalogue [2].

2 General concepts

As an alternative to traditional techniques and materials, hot recycled asphalt concrete (HRAC), cold recycled asphalt mixture (CRAM), cement treated recycled mixture (CTRM), microsurfacing and surface dressing have been introduced as new methods to be used for the maintenance of the road pavements in the Republic of San Marino.

Particularly, for HRAC, an accurate management and quality control of raw materials and products were established to allow no limitation to the amount of the reclaimed asphalt (RA) to be recycled. This approach stimulates the accurate management of RA, the innovation in the production chain and the optimization of the hot recycling process without sacrificing the mixture performance.

Two important aspects must be emphasised for CRAM, firstly, its production and application at ambient temperature, with significant reduction of energy consumption and emissions, and lastly, the use of RA in place of virgin aggregates up to 100 %, with important advantages in terms of preservation of natural resources and management of landfill storage. Likely, CTRM can use 100 % of Construction and Demolition waste (C&D) in place of virgin aggregates.

Finally, surface dressing or microsurfacing are often an effective alternative to hot traditional asphalt concrete for surface courses since they allow operating in a speedy manner and at ambient temperature with considerable advantages of both the management of the construction site and environmental impact.

For each new material and technique, San Marino road administration decided to act following three steps to adapt and control the stakeholders gradually: selection and mix design of the eco-sustainable technique in laboratory, building of a trial section at the mix plant, building of a demonstration site on a sectioned road and, after one-year monitoring of the demonstration site, complete implementation of the selected technique in the maintenance project method.

Indeed, when the contractor cannot demonstrate a solid experience on the above mentioned eco-sustainable techniques, the road administration can request and coordinate a trial section to be built inside the mix plant yard considering a minimum size of 350 m^2 (100 m × 3.50 m and thickness as stated in the design). The trial section aims at the validation of the full scale production of the mix design, the simulation of the construction site and the monitoring of the production stability. The production of the mixture to be validated must not be less than 90 t [3, 4].

3 Reclaimed asphalt and recycled aggregates

The RA and the C&D have to be crushed and screened into at least two fractions to reduce the variability of particle grading and characteristics. RA and C&D fractions have to be stockpiled and protected by rainfall and direct soral irradiation under open air sheds. Each fraction of RA has to be designated complying with the EN 13108-8, while each fraction of C&D has to be designated complying with the EN 13242. The constituents of coarse recycled aggregate has to be declared following the EN 933-11.

Additionally, maximum size, shape index (SI), flakiness index (FI), gradation of RA and aggregates (washed method) and bitumen content have to be declared in terms of average and coefficient of variation values for each RA fraction. Whereas, maximum size, SI, FI, gradation aggregates (washed method) and plasticity index have to be declared in terms of average

and coefficient of variation values for each C&D fraction. Moreover, clay masonry units (i.e. bricks and tiles), calcium silicate masonry units, aerated non-floating concrete (R_b), glass (R_g) and cohesive (i.e. clay and soil), miscellaneous, metals, non-floating wood, plastic and rubber, gypsum plaster (X) cannot exceed 5 % by volume of the total mixture and plasticity index has to be less than 6. RA and C&D have to show SI and FI values less than 30 %.
Statistics have to consider at least 5 samples when the total amount of RA or C&D to be used in the project is less than 2,500 t or 1 sample every 500 t when higher RA or C&D amount is involved. The RA and C&D contents have to be declared for every mixture. Recycled blends have to be monitored daily or every 5000 m^2 of paving to check the production stability [1].

4 Hot recycled asphalt concrete

For HRAC there is not an upper limit for RA contents. Requirements, in terms of constituents and performance, do not differ from those of asphalt concrete AC20 and AC16. However, strict requirements to RA, rejuvenator and product are imposed in quality control phase as described in the previous chapter [5, 6]. HRAC is generally used for binder course since base courses are generally built using cold techniques such as CRAM or CTRM [1].

5 Cement treated recycled mixture

The CTRM can contain up to 100 % of RA and C&D. CTRM is produced in mobile or stationary mixing facility has to be laid down by means of a paver and immediately compacted using both a tandem drum vibratory roller and a pneumatic-tired roller. CTRM can be used for base and foundation courses considering thickness higher than 10 cm. The course has to be built in two lifts when the thickness exceeds 20 cm. When used as foundation course in utility trenches layer lift cannot exceed 25 cm.
The cement type CEM I (Portland cement), II (composite Portland cement with fly ash, slag and limestone), III (blast furnace cement), IV (pozzolanic cement varieties) and V (Composite cement) complying with EN 197-1 can be used with no specific restrictions.
Two gradation bands are specified depending on the layer thickness: CTRM20 for 10-15 cm thick layers, CTRM30 for 15-25 thick layers [8]. The granular blend (not including cement) should have a CBR value higher than 50 and no vertical swelling after 4 days of immersion in water (EN 13286-47). The volumetric and mechanical characteristics of the CTRM have to be determined through a Proctor compactor (EN 13286-2) according to the following parameters: energy of 2.7 MJ/m^3 (modified), mould diameter of 150 mm, thickness mould of 120 mm, 56 blows per layer for 5 layers to define the optimum water content and ITS values (EN 13286-42). While the procedure requires a thickness mould of 180 mm, 85 blows per layer for 5 layers to define the unconfined compressive strength (UCS) values (EN 13286-41).

Table 1 Mix design procedures for CTRM

Optimum water content – first phase			
Cement	[% by aggregate mass]	4	Dry density
Water	[% by aggregate mass]	4, 5, 6 and 7	
Optimum cement content – second phase			
Curing process: 7 days at 25 °C in sealed condition			
Water	[% by aggregate weight]	optimum	ITS ≥ 0,30 N/mm^2; UCS = 3,0 - 5,0 N/mm^2
Cement	[% by aggregate weight]	3, 4, 5	

The CTRM recipe has to be established following a specific mix design method (Table 1) consisting of two phases: the first phase defines the optimum water content and the second phase defines the optimum dosage of cement. The characteristic average values have to be obtained from at least three specimens with coefficient of variation expressed as a percentage lower than 15 % [1].

6 Cold recycled asphalt mixture

The CRAM can contain up to 100 % of RA and is produced in mobile or stationary mixing facility. CRAM has to be laid down by means of a paver and immediately compacted using both a tandem drum vibratory roller and a pneumatic-tired roller. CRAM can be used for both binder and base courses considering thickness higher than 10 cm. The course has to be built in two lifts when the thickness exceeds 20 cm. The underneath layer has to be characterised by a modulus measured by static plate load test higher than 80 MPa.
The cement type CEM I, II, III, IV and V complying with EN 197-1 can be used with no specific restrictions. CEM II is recommended when RA has low filler content (lower than 2 %).
The bituminous emulsion has to be a polymer modified emulsion designated as C60PB10 according to the EN 13808.
Two gradation bands are specified depending on the layer thickness: AC20 for 10-15 cm thick layers, AC30 for 15-20 thick layers. The volumetric and mechanical characteristics of the CRAM have to be determined through a gyratory compactor (EN 12697-31) according to the following parameters: fixed energy of 100 revolutions, inclination angle of 1.25 ± 0.02, mould diameter of 150 mm, wet sample mass of 2,800 g. The CRAM recipe has to be established following a specific mix design method (Table 2) consisting of two phases: the first phase defines the optimum water content and the second phase defines the optimum dosage of binders [7]. The characteristic average values have to be obtained from at least three specimens with coefficient of variation expressed as a percentage lower than 15 %.

Table 2 Mix design procedures for CRAM

Optimum water content – first phase			
Cement	[% by aggregate weight]	2	Maximum Dry density; Leaking water ‹ 0.5 %
Water	[% by aggregate weight]	3; 4; 5 and 6	
Optimum binder content – second phase			
Curing process: 72 hours at 40 °C in unsealed condition			
Water	[% by aggregate weight]	optimum	ITS @ 25°C ≥ 0,40 MPa; ITSR ≥ 80 % ITSM @ 20°C ≥ 3000 MPa
Cement	[% by aggregate weight]	1.5; 2.0 and 2.5	
Emulsion	[% by aggregate weight]	4.0; 4.5 and 5.0	
Ratio between bitumen and cement contents › 1			

Indirect tensile strength (ITS), indirect tensile stiffness modulus (ITSM) and indirect tensile strength ratio (ITSR) are determined complying with EN 12697-23, EN 12697-26 and EN 12697-12, respectively [1].

7 Surface dressing

Surface dressing consists of at least one layer of binder and at least one layer of chippings. The surface dressing aims at sealing the pavement, improving the skid resistance and harmonising the road in a rural context. The most common and recommended method for rural roads requires three layers. The main requirements for the surface dressing are reported in Table 3 [1].

Table 3 Requirements for surface dressing

Layer	**Emulsion**	**Dosage of emulsion** [kg/m²]	**Aggregate fraction**	**Dosage of aggregate** [l/m²]
First	C55B3	3.0	8/12 G_C90-15	9-10
Second	C65B3 or C65BP3	1.5	8/12 G_C90-15	9-10
Third	C65B3 or C65BP3	1.5	4/8 G_C90-15	6-7

8 Microsurfacing

Microsurfacing is a bituminous mixture consisting of a well-graded basaltic aggregate blend, water, modified bituminous emulsion and Portland cement [9]. Microsurfacing is proportioned, mixed and uniformly laid in-place over a properly prepared surface. Microsurfacing is applied as a homogeneous mat, seals and adheres firmly to the pavement, and have a high skid-resistant texture throughout its service life. Microsurfacing may consist of one or more layers (usually in a thickness of the largest aggregate size in the gradation) and can be used over old or new pavements.

The cement type CEM I, II, III, IV and V complying with EN 197-1 can be used with no specific restrictions.

The bituminous emulsion has to be a polymer modified emulsion designated as C60PB4 according to the EN 13808. Different setting time can be selected considering specific climate conditions.

Two gradation bands are specified depending on the maximum size that can be 4 or 8 mm. Generally the 0/4 mixture is used underneath the 0/8 mixture when two layers have to be applied. The microsurfacing recipe has to be established following a specific mix design method (Table 4). The characteristic average values have to be obtained from at least three samples with coefficient of variation expressed as a percentage lower than 15 % [1].

Table 4 Performance required for microsurfacing

Parameters	**Standard**	**Units**	**Requirement**
Wearing after 1 hour of immersion	EN 12274-5	[g/m²]	‹ 500
Cohesion after 30 min	EN 12274-4	[N·m]	≥ 1.2
Cohesion after 60 min	EN 12274-4	[N·m]	≥ 2.0
Consistency	EN 12274-3	[mm]	25 - 35

9 Catalogue for structural design

A catalogue for structural design was defined to facilitate the preliminary choices and to force the use of eco-sustainable techniques. The schemes reported in Figure 1 have to be considered as the minimum structures (minimum thickness and minimum layer number) and can be only adopted for roads with low traffic volume, i.e. average daily traffic (ADT) lower than 5,000 vehicles per lane and commercial vehicles lower than 10 % of the ADT [10]. For roads with higher ADT, the catalogue provides the designer with the preliminary schemes to be validated and optimised using the mechanistic-empirical design method [2].

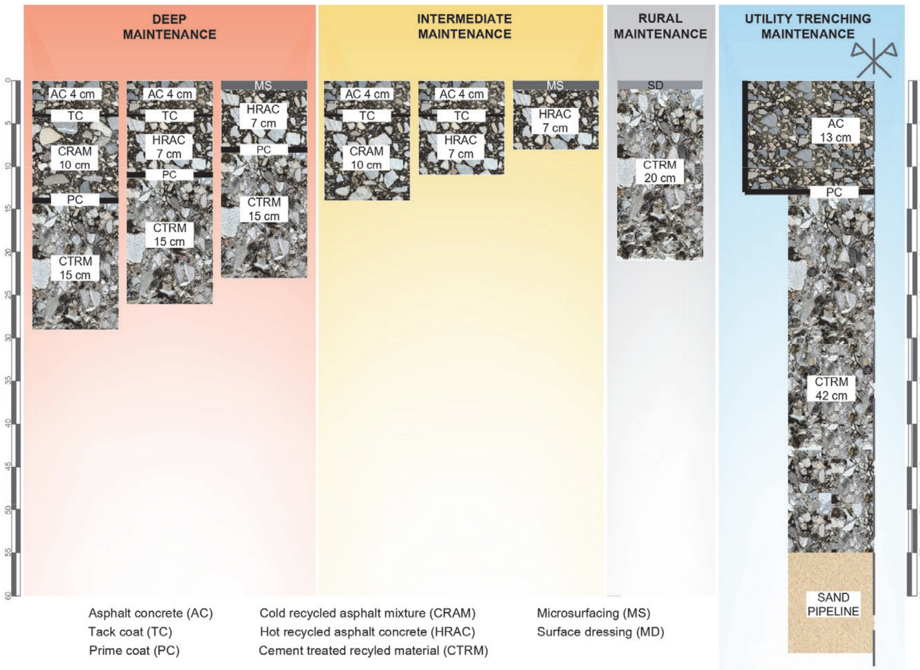

Figure 1 Structural design catalogue

10 Experiences learnt and perspectives

Considering a gradual changing from traditional to eco-sustainable techniques and the required procedures from 2018 to 2020 about 1.000 t of HRAM, 300 t of CRAM and 3.000 t of CTRM were used for road and utility trench maintenance in the Republic of San Marino involving the recycling of more than 2.000 t of RA and 1.500 t of C&D. Results appeared immediately promising and stimulated new concept for road maintenance and management of RA and C&D. Particularly, RA and C&D cannot be underestimate as waste materials but accurately managed and treated to be used in place of virgin aggregates favouriting the circular economic. Additionally, cold treatment and mixture significantly reduce the environmental impact of mix plants.

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