Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

ECOMONDO, The Green Technology Expo
8th – 11th November 2022, Rimini, Italy

COLD ASPHALT CONTAINING 100% RECLAIMED ASPHALT: A SUSTAINABLE TECHNOLOGY FOR CYCLE PATHS AND MAINTENANCE INTERVENTIONS*

Paola Di Mascio[1], Nicola Fiore[2], Antonio D'Andrea[1], Carlo Polidori[3], Loretta Venturini[4]**

[1]Prof. Dr. Docent, Università di Roma La Sapienza, Piazzale Aldo Moro, 5, 00185 Rome, Italy
[2]Eng. Università di Roma La Sapienza, Piazzale Aldo Moro, 5, 00185 Rome, Italy
[3]AIPSS – Associazione Italiana Professionisti Sicurezza Stradale, Via Bergamo, 3, 00198, Rome, Italy
[4]PhD. Eng., Iterchimica S.p.A., Via Guglielmo Marconi 21, 24040, Suisio, Bergamo, Italy

Abstract

Both the National Recovery and Resilience Plan (Next Generation EU Program) and the development strategies for Smart Cities focus on cycle and pedestrian paths. Their pavements must be safe, durable and sustainable and considering the need to preserve the resources that Planet Earth offers to humans, it is essential to opt for innovative construction technologies that allow recycling methods without necessarily involving the addition of first-use materials.
In the field of road infrastructure, the recovery of material deriving from the demolition of old pavements (RA - Reclaimed Asphalt) is only possible thanks to the use of specific products. A state-of-the-art rejuvenator is currently being used for the construction of cycling paths with 100% cold-mixed RA.
This product is currently being studied for the INFRAROB project: "Maintaining integrity, performance and safety of the road infrastructure through autonomous robotized solutions and modularization" (Horizon 2020) with particular reference to "potholes patching" materials.
Some technical data of the experiences developed to date are shown below.

Keywords: circular economy, cycle path, Green Deal, recycle.

1. Green Deal and cycle paths

The European Green Deal aims to achieve zero emissions by 2050, also through the development of policies for a circular economy. With the Paris Agreement, the EU made a commitment to reduce greenhouse gas emissions by at least 40% by 2030, compared to 1990 levels, but in 2021 it raised the target to at least 55%. The package of reference is "Fit for 55%", which includes the revision of the existing legislation on emission reduction and energy, ensuring a fair and socially just transition, strengthening innovation and industry competitiveness, and supporting the EU's leading position in the global fight against climate change (Chamber of Deputies, 17 December 2011).

It is acknowledged, among other things, that "circular economy" means the reintroduction of waste products at the end of their service life into new production cycles, in order to minimise, and if possible, eliminate negative effects on the environment. Such actions make it possible both to avoid the accumulation of waste in landfills and to exploit resources, especially non-renewable ones. It should also be pointed out that there is a close correlation between energy efficiency and circular economy (United Nations, 2006).

Recently, in July 2022, the European Commission highlighted the fundamental contribution of cycle paths to achieve sustainability, supporting a strategy that aims to encourage cycling to reduce dependence on fossil fuels and to mitigate emissions into the environment, leading to improved air

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: loretta.venturini@iterchimica.it

quality in urban areas. By 2025, the proposal for new rules for investments in the transport network includes the requirement for a plan to make urban mobility “clean, sustainable and emission-free”, with particular reference to cities with more than 100,000 inhabitants (Baccini, 2022). It is obvious that stimulating the use of cycle-pedestrian paths necessarily leads to an implementation of the infrastructural system. In fact, the number of cycle paths is planned to double by 2030.

The right importance of bicycle lanes within the urban mobility system is unfortunately not so taken for granted, even though the bicycle is extremely versatile: it does not produce noise and environmental pollution, for the same mobility it means less parking and less deterioration of the road network, it implies less congestion and a relative decrease in wasted time, excellent daily exercise (not to be underestimated from a social point of view), etc. (Gaballo, March 2021). Some new recent studies show that the main needs that influence the choice of bicycle use are enjoyment of bicycling, safety, and comfort (C. G. Thigpen, 2015).

Contextualising the abovementioned to the asphalt pavement sector, also for cycle paths, there are innovative technological solutions that fit perfectly within the tools to achieve the Green Deal. Certainly, along with increased performance and reduced maintenance, the recycling of pavements at the end of their service life is an essential component in reducing the carbon footprint. The material resulting from the demolition of pavements is known in Italy as “granulate of bituminous mix or, in jargon, milled material” and internationally as RAP - Reclaimed Asphalt Pavement.

2. Asphalt pavements for cycle paths

In Title I, Art. 3, the Italian Highway Code defines the concept of “bicycle lane” as the longitudinal part of the carriageway, normally on the right, delimited by a white strip, continuous or discontinuous, intended for the circulation on the roads of velocipedes in the same direction of travel as other vehicles and marked by the velocipede symbol (Legislative Decree, 30 April 1992). The type of route depends substantially on the areas where the pavement is laid and can be, for example, shared with car traffic, on country roads or roads with low traffic density, precluded to car traffic, etc.

In the context of a circular economy, it is essential to limit the construction of infrastructure as much as possible, either by rehabilitating abandoned infrastructure or by using secondary road networks such as disused roads, service roads, embankments, country roads, sidewalks, embankments, service roads, etc. In any case, the asphalt pavement must not only be safe, but also durable and easily recognizable to users. Therefore, the two main obstacles to overcome are the environmental impact and the small allocated spending budgets (Lombardy Region, Manual for the Implementation of the Regional Cycle Network, August 2022).

The structural solutions mainly used are: 1 – asphalt concrete pavement, which is the most widely used solution in all contexts because it gives a safer and more durable wheel-rolling surface; 2 - granular pavement (possibly treated with protective treatments or emulsifiers), which is especially suitable in suburban areas in the countryside, hills, mountains, etc, and in general where it is desired to reduce the architectural impact at a very low cost; 3 – special pavements, used in exceptional situations as they are expensive and not very comfortable for cyclists (block paving, cobblestones, interlocking paving, etc.).

Focusing on AC flexible pavement, the wearing course of the bituminous mix is the top layer, and its function is not only to provide a safe and durable surfacing, but it must be smooth, skid resistant, dust-free, waterproof, long-lasting and protective of the underlying courses (Department of Planning, January 2015).

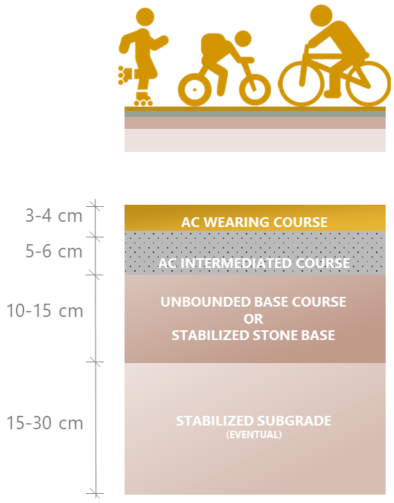


Fig. 1. Typical section of a cycle path

As with all road infrastructures with one or multiple layers, the section of a cycle track is usually made up of a series of asphalt layers, laid on a sub-base, according to typical construction techniques (Fig. 1). For example, the typical cross-section for newly constructed cycle paths consists of a stabilized subgrade (or existing soil) of approx. 20-40 cm, a 10-20 cm thick bituminous bonded or unbounded base course, an AC (Asphalt Concrete) intermediate course of 5-6 cm and an AC wearing course of approx. 3-4 cm. Please note that for cycle paths built using existing asphalt pavements it is often only necessary to resurface the wearing course by approx. 3-4 cm. The determination of thicknesses is always an engineering choice that depends substantially on loads and environmental conditions. It must be considered that the asphalt pavement is sometimes used by more or less light and/or more or less fast traffic, especially for cleaning and maintenance of the cycle path. Without forgetting that, in the case of surmountable signage, the track is often mistakenly used by cars for short stops and overtaking manoeuvres (Fig. 2).

Fig. 2. Cars parked on the cycle path

3. Innovative and sustainable asphalt concrete for cycle paths

3.1. 100% Cold rejuvenated RAP

Asphalt mixes are mixtures of bitumen (waste from oil processing) and aggregates (they can be of different kinds), which also contain RAP in different percentages depending on the design choices and the relevant technical standards. Recycled RAP is almost always returned into the new asphalt concrete pavement in different forms: sometimes used as an aggregate in base or subbase construction, but generally it is incorporated in the new asphalt concrete (AC) using hot recycling technique, exploiting the full potential of the bitumen contained. In terms of sustainability, the use of RAP for the production of the new mixtures implies a reduction in the amount of material to be landfilled, a substantial decrease in soil consumption and new raw or first-use materials.

Speaking about traditional AC and bike trails, the main performances to be met/checked are cracking and rutting resistance, and durability. When using RAP, even for cycle paths, it is clear that it is necessary to proceed with the rejuvenation of the aged bitumen. The RAP should meet the specifications identified by local laws. Furthermore, we should not forget that the pavement of the cycle paths must be designed like any other pavement (D. Simpson, June 2012). When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement (bitumen) (Federal Highway Administration, August 2016). By using a milling machine or a rhino horn on a bulldozer and/or pneumatic pavement (full-depth removal), the broken material must be treated and processed, including crushing, screening, conveying, and stacking. This procedure is very important because the properties of RAP depend on the original constituent materials and the type of asphalt concrete mix from which they derive (wearing course, binder course, etc.). For example, the wearing course aggregates normally have higher quality than the aggregates in binder course applications, where polishing resistance is not of concern.

In addition to the proper treatment of RAP, especially for the recovery in HMA mixtures, a further “problem” to be managed is the ageing of the bitumen. Due to its organic nature (a residue of oil distillation), the bituminous binder undergoes a chemical-physical transformation over time (Phase 1 - production and storage of bitumen; Phase 2 - production, storage and laying of asphalt; Phase 3 - service life of the pavement) that leads to its deterioration through the evaporation of the volatile components and the oxidation process, resulting in a decrease in mechanical performance, loss of adhesiveness, increase in stiffness values and consequently increasingly fragile behaviour. For the processing of RAP, it is essential to highlight the difference between “rejuvenate” and “reuse”. The two main categories of recycling products are: softening agents (softeners) and rejuvenating agents (rejuvenators). A softening agent action is the reduction of viscosity and softening point, and the increase of penetration of the final binder. However, the permanence of the effect is not guaranteed since the modification is limited to physical and rheological properties. This category includes flux oils from different origins (organic or inorganic). A rejuvenating agent has instead partially or totally the capacity to restore the lost chemical features of the RAP and the properties of its aged bitumen as well as recovering the physical and rheological features. The level of successful recycling is highly dependent on the correct choice of the type and quantity of the recycling agent. Recycling agents play a key role also in the recycled mixture’s performance and durability of new HMA, but nowadays it’s possible to distinguish between rejuvenator and flux oil, using laboratory tests (V. Loise).

During the last decade and as a result of several years of research, a new method of recycling of 100% reclaimed asphalt at ambient temperature (CMRA with 100% RAP - cold mix recycled asphalt with 100% reclaimed asphalt pavement) was developed, rejuvenating the aged bitumen with a new, specially formulated rejuvenator. In this manner, the saving in terms of energy and economic aspects is evident (zero emissions, material recovery and no energy consumption). In the rejuvenation process, the innovative rejuvenator allows to return the chemical ratio back in balance, restoring the bitumen composition to its original state or as close to it as possible. In particular, despite being initially designed for the production of bituminous mixtures for pothole patching, road maintenance and rehabilitation works, thanks to the high performances achieved, the CMRA with 100% RAP could be used as an alternative to HMA for cycling paths and light-traffic roads.

The innovative rejuvenating agent is a liquid additive free of aromatic substances with hydrocarbon binder enriched with rejuvenators, plasticizers, vegetal flux oils, anti-oxidative chemicals and moisturizer diluent (Tab. 1). This material is otherwise compatible with different kinds of colouring pigments.

Characteristic	**Value/Description**
Aspect	Fluid substance
Colour	Brown
Density at 20˚C	0,94 ± 0,02 g/cm3
Viscosity	400 - 500 cP
Flash point	> 150°C

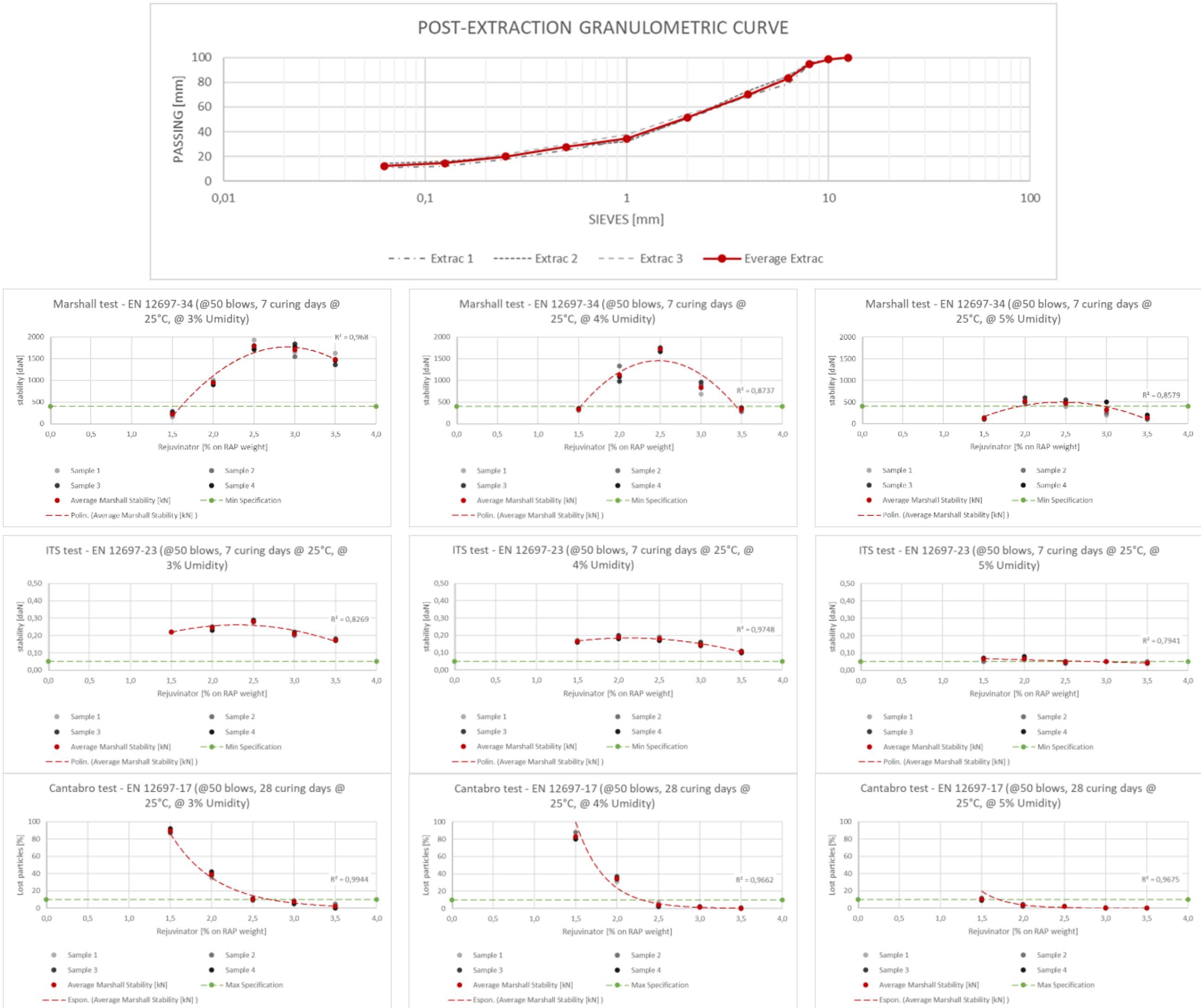
Tab. 1. Some of the given physical properties of rejuvenating/binder

Considering also the area of application, the special bituminous mixtures produced with this technology evidently require a dedicated verification method that cannot be the same as HMA (Hot Mix Asphalt) and WMA (Warm Mix Asphalt). The technical standards of the Municipality of Milan and the Lombardy Region report a verification process that highlights the advantages of this technology compared to traditional CMA. The required performances are shown in Tab. 2 (Lombardy Region & Municipality of Milan, Technical Specifications Volume – Price list of public works, 2021).

Test	Test method	Unit of measurement	Values required
Compaction	UNI EN 12697-34	Blows per side	50
Marshall Stability after 7 days in the open at 25°C	UNI EN Test Method 12697-34	kN	> 4
Indirect Tensile Strength after 7 days in the open at 25°C	CNR n.134/91	kPa	> 50
Cantabro particle loss after 28 days of conditioning at 25°C, 300 rotations at a speed rate of 30 rotations/min, using Los Angeles machine without abrasive charge	---	%	< 10

Tab. 2. *Procedure for the performance testing of CMRA with 100% RAP*

The results of a mix design study using the abovementioned procedure are shown below (figures 3).



Figures 3. *Mix design of cold mix recycled asphalt with 100% RAP*

3.2 European project and performance of sustainable CMRA with 100% RAP

A study on the CMA with 100% RAP and rejuvenator was performed also for the project InfraRob, a research project funded by the European Commission's research programme Horizon 2020 aiming at maintaining integrity, performance, and safety of the road infrastructure through autonomous robotized solutions and modularization. A specific task of the project is focused on the development of a system able to extrude a specific mixture for filling in small cracks and potholes. Grading, Marshall Stability, void content, indirect tensile strength, and particle loss have been studied ranging the additive content from 1.5% to 3.5% and the water content from 3.1% to 5%. The maximum size of the aggregate was limited to 8 mm, due to the size of the potholes to be treated in the project. The mixing and compaction process of the specimens were performed at room temperature. The specimens' compaction was carried out with 50 strokes of Marshall's hammer, considering the reduced compaction ability of the material in a restricted area. The Marshall Stability and the indirect tensile strength were carried out at 25 ° C after a period of curing of 7 days at the same temperature in a ventilated oven. The particle loss has been studied with the Cantabro test according to EN 12697-17 after a curing period of 28 days at 25°C. Eight totally different mixes were tested and the results are listed in Tab. 3.

COLD MIX	Reference standard	RECYCLING AGENT FOR 100% RAP (CMA)							
Mixture		A	B	C	D	E	F	G	H
Recycling agent [%]		1.5%	2.0%	2.5%	3.0%	3.0%	3.0%	3.5%	3.5%
Water content [%]		3.1%	3.1%	3.1%	3.1%	4.0%	5.0%	4.0%	5.0%
Bulk density [g/cm³]	EN 12697-6	1.97	2.05	2.08	2.13	2.11	2.12	2.1	2.11
Maximum density [g/cm³]	EN 12697-5	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47
Air voids [%]	EN 12697-8	20.3	17.3	15.8	13.8	14.6	14.4	14.8	14.8
Indirect tensile strength 7dd [N/mm²]	EN 12697-23	0.18	0.19	0.19	0.23	0.12	0.12	0.04	0.09
Marshall Stability 7dd [daN]	EN 12697-34	908	1043	1055	1285	612	603	246	403
Particle loss 7dd [%]	EN 12697-17					84	76	84	83
Particle loss 28dd [%]	EN 12697-17	95	46	20	13	3	5	0	3

Tab. 3. *Mixtures laboratory test results.*

Since the Cantabro test does not respond exactly to the damage produced by the traffic, the material has been laid down in some potholes and it was monitored under traffic. Four potholes 10 cm deep and 10 cm as diameter were dug in the parking lot annexed to the school of Engineering of Sapienza-University of Rome.

The potholes were filled with mixtures E and F listed in Tab. 3. The four potholes' repairs were loaded with a road vehicle (FIAT Doblò), immediately after laying and they were monitored after 50 and 100 passages of the vehicle. The surveys were carried out visually to verify that there are no losses of material, even immediately after laying, when the material is not cured and just self-compacted. The in-situ mix tests show a good thickening and absence of disintegration of the material or loss of cohesion, even immediately after laying. The passages were repeated thirty days later and the material was found stable and without distresses. So far, after two months under traffic, the filling material is in place and no detachment or raveling is revealed.

3.3 CMRA with 100% RAP for cycle paths

The Grande Raccordo Anulare delle Biciclette (Bicycle Ring Road), also known as GRAB, is the first cycle route in the City of Rome, consisting of a ring of approximately 50 km that ideally has its km 0 at the Colosseum - San Gregorio Street. The project was preliminarily approved in April 2018, with funding from the Ministry of Infrastructure and Transport. Today, the project is part of the sustainable development plan for the city, allowing for a review of the mobility from the point of view of everyday travel (e.g. home-work and home-school) and for tourist approaches in an area full of history and natural resources. Today, the project is in its final phase with the collaboration of the Sapienza - University of Rome.

The cycle path is articulated in 6 Lots with different characteristics: it has a separated 3.5 m wide carriageway (where there is the need to reconfigure the spaces intended for vehicle traffic or to extend the existing cycle paths); in certain parts it is a recognizable path, but separate from the pedestrian path; it is an integral and main part of the road for example near the archeological sites along the Via Appia Antica (Mobility of Rome, 2022). With particular reference to the sections being newly resurfaced and built, in February 2022 a trial section was carried out using CMRA with 100% RAP. It consisted of a 140-metre long by 2-metre wide (with a thickness of 3 cm) section in Via del Campo Boario and a 84-metre long by 3-metre wide (with a thickness of 3 cm) second section in Via Nicola Zabaglia. The work phases included the demolition of the old pavement, the in-plant production of the innovative mix and the laying using a paver and a rolling machine.

The laboratory analysis for the verification of the mixture was carried out by the Road Laboratory of Sapienza-University of Rome.

4. Conclusions

The reuse of waste products and the promotion of cycle and pedestrian paths both urban and rural environment are two interventions that Europe is focusing on to protect the environment. A lucky marriage of the two was presented in this article. The use of a cold asphalt mixture composed of 100% RAP and an innovative bitumen rejuvenator has been proposed. The material was studied at the Road Materials Laboratory of Sapienza - University of Rome as part of the European Infrarob project for the robotic repair of the road potholes. Laboratory and on-site tests have revealed a good behavior of the material which is resistant and long-lasting. The material has already been applied for the construction of cycle paths in various Italian cities, demonstrating a good flexibility of application.

Acknowledgements

The authors would like to acknowledge A.S. Appalti Stradali S.r.l. and Iterchimica’s Laboratory for their contributions in managing and carrying out the project discussed in this paper.

References

Baccini, F. (2022). *La Commissione UE studia una strategia per la mobilità su due ruote: "Un'Europa verde sarà un'Europa ciclistica".*

C. G. Thigpen, S. H. (2015). Modelling the Impact of Pavement Roughness on Bicycle Ride Quality. *Transportation Research Record Journal of the TRB.*

Camera dei Deputati. (17 Dicembre 2011). *Pacchetto "Pronti per il 55%" (FIT for 55%): la revisione della normativa in materia di clima*. Roma: Ufficio Rapporti con l'UE.

D. Simpson, W. B. (June 2012). *Best practices for bicycle trail pavement construction and maintenance in Illinois.* Urbana-Champaign Illinois - USA: Illinois Center for Transportation.

Decreto Legislativo. (30 aprile 1992). *Nuovo codice della strada - decreto legislativo n. 285 e successive modificazioni.*

Department of Planning. (January 2015). *Guide to Bikeway Pavement Design Construction & Maintenance for South Australia.* Government of South Australia: Transport and Infrastructure Safety and Service Division.

European Commission. (2022). *Circular Economy Action Plan 2022*. Tratto da https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en#actions

Federal Highway Administration. (August 2016). *User Guidelines for Waste and Byproduct Materials in Pavement Construction,* USA: FHWA-RD-97-148.

Gaballo, F. (Marzo 2021). *Sovrastrutture prefabbricate ed ecocompatibili per piste ciclabili, Gaballo*. Torino: Politecnico di Torino, Facoltà di Ingegneria, Corso di Laurea Magistrale in Ingegneria Civile.

Mobilità di Roma. (2022, luglio 26). *GRAB, la ciclovia romana*. Tratto da Roma Mobilità: https://romamobilita.it/it/progetti/pumsroma/grab-ciclovia-romana

Planning, D. o., & Transport and Infrastructure Safety and Service Division. (January 2015). *Government of South Australia*. Government of South Australia.

Regione Lombardia. (Agosto 2022). *Manuale per la realizzazione della rete ciclabile regionale –*. Milano. Tratto da www.regione.lombardia.it

Regione Lombardia, & Comune di Milano. (2021). *Volume specifiche tecniche - Prezzario delle opere pubbliche*. Milano: Provveditorato interregionale per la Lombardia e l'Emilia Romagna.

United Nations, E. (2006). *PRODEV: Supporting the circular economy development of Guiyang*.

V. Loisea, P. C. (s.d.). *Unravelling the role of a green rejuvenator agent in contrasting the aging effect on bitumen: A dynamics rheology, nuclear magnetic relaxometry and self-diffusion study*.