LIFE Project Number

**LIFE10 ENV/IT/000390**

# -------- ABSTRACT --------

**Covering the project activities from 01/09/2011 to 30/09/2015**

Reporting Date

**29/02/2016**

LIFE+ PROJECT NAME or Acronym

**TYREC4LIFE**

Project Data

| | |
|---|---|
| **Project location** | PIEMONTE region |
| **Project start date:** | 01/09/2011 |
| **Project end date:** | 31/08/2014 **Extension date:** 30/09/2015 |
| **Total Project duration (in months)** | 49 months ( including **Extension of 13 months**) |
| **Total budget** | € 3.199.984 |
| **Total eligible budget** | € 2.195.103,18 |
| **EU contribution:** | € 1.244.492 |
| **(%) of total costs** | |
| **(%) of eligible costs** | |

Beneficiary Data

| | |
|---|---|
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Contents

# 1. Executive Summary

The TYREC4LIFE project focused on the development and implementation of innovative technologies which can expand the use of scrap tyre rubber in road pavements. Emphasis was placed on the evaluation of solutions which may provide an optimal balance in satisfying technical, financial and environmental requirements. Issues which were addressed in the project included users' safety and comfort, structural durability of pavements, reduction of environmental impact, safety and health of working crews.

Relevance from an environmental viewpoint of the topic addressed by the project can be appreciated by considering the growing need of maximizing the recycling of end-of-life tyres (ELTs) according to current European legislation. Moreover, past studies and experiences proved that crumb rubber derived by size-reduction from ELTs may be effectively used in paving applications as an additional component of bituminous mixtures.

Regardless of their positive performance records, paving solutions encompassing the use of crumb rubber from ELTs, which are nowadays accepted as standard in some Countries (e.g. several States in USA, Portugal, Spain), are still limited in their diffusion in great part of Europe as a consequence of the lack of previous direct experience and of locally validated Technical Specifications. This is also the case of Italy, where full-scale applications have been regarded as experimental trials, with few comprehensive supporting studies and no complete validation of their effective performance in service.

The TYREC4LIFE project was conceived and proposed for funding to the European Commission in such a context. Its engineering starting point at the local scale was constituted by the results of previous investigations carried out since 2008 by the Città Metropolitana di Torino, formerly Provincia di Torino, and by the Politecnico di Torino. These studies, which included the construction of a pavement trial section, focused on the application of the so-called "wet" technology, by means of which crumb rubber from ELTs is pre-mixed with bitumen, thus yielding a ductile and elastic binder known as "asphalt rubber". Corresponding bituminous mixtures were designed by referring to the classical "gap-graded" formulation, which in literature has been reported to yield a satisfactory field performance both from a structural and functional viewpoint. Due to their controversial performance records, only a minor portion of the investigations was dedicated to bituminous mixtures produced by means of the "dry" technology, in which crumb rubber from ELTs is directly added into the mixer of the hot mix plant in partial substitution of fine aggregates.

Based on the experience synthesized above and by considering the general need of supporting the widespread acceptance and diffusion of paving solutions involving the use of crumb rubber from ELTs, the following main four technical objectives were set for the TYRE4LIFE project:

- Objective n. 1: Validation of the use of bituminous mixtures with alternative formulations;
- Objective n. 2: Evaluation of the potential use of reduced-quality or recycled aggregates;
- Objective n. 3: Development of solutions for the reduction of energy consumption and emissions;
- Objective n. 4: Preliminary implementation of the "dry" technology.

In order to reach these objectives, the project was structured in Actions which were grouped as indicated in the following:

- Action 1 - Project management;
- Action 2 - Evaluation;
- Action 3 - Experimental investigations and technological development;
- Action 4 - Implementation;
- Action 5 - Life Cycle Risk Assessment;
- Action 6 - Communication and dissemination;
- Action 7 - After-LIFE Communication plan;
- Action 8 - Overall project monitoring.

Objectives n. 1 and n. 2 of the TYREC4LIFE project were reached mainly by means of the following technical Actions:

- Action 2.4, which considered the characteristics of locally available aggregates to be employed for the production of bituminous mixtures, including bottom ashes coming from the newly constructed waste incinerator of the City of Torino;
- Action 2.5, which analysed the characteristics of crumb rubber originated from different production processes potentially available for the production of asphalt rubber binders by means of the “wet” process;
- Actions 3.1 and 3.2, which focused on the rheological characterization of asphalt rubber binders and on the volumetric and mechanical mix design and performance-related assessment of bituminous mixtures with variable composition;
- Actions 4.1 and 4.2, which consisted in the full-scale construction of pavement sections by employing purposely-designed gap-graded and dense-graded mixtures containing asphalt rubber, laid on site according to different cross-section schemes;
- Actions 4.3 and 4.4, which provided experimental evidence of the structural, functional and sanitary-environmental performance of the pavement trial sections built as part of Actions 4.1 and 4.2;
- Action 3.6, which, as a supplement to the initial research program, considered the design and full-scale use of dense-graded bituminous mixtures containing recycled asphalt pavement (RAP) material.

Objective n. 3 was reached mainly by means of the following Actions:

- Action 3.1, which considered the effects of viscosity-reduction additives on the rheological behaviour of asphalt rubber binders;
- Action 4.1, in which a gap-graded bituminous mixture containing a low-viscosity asphalt rubber binder was laid on a reduced-scale trial section and thereafter optimized in the laboratory with respect to its composition;
- Action 3.4, which entailed the production and laying of “dry” bituminous mixtures containing a viscosity-reduction additive.

Objective n. 4 was reached mainly by means of the following Actions:

- Actions 3.3.1 and 3.3.2, which focused on the design and construction of a full-scale prototype device for the production of “dry” bituminous mixtures;
- Actions 3.4 and 3.5, in which reduced-scale pavement sections were built by employing mixtures for wearing courses and base courses produced by means of the above mentioned prototype device.

In reaching all four objectives of the project the following Actions were also of paramount importance since they contributed to the definition of the context within it was developed:

- Action 2.1, which addressed the general subject of end-of-life vehicles (ELVs) and end-of-life tyres (ELTs) with respect to the achievement of European targets in terms of recycling and recovery;
- Actions 2.2 and 2.3, which focused on the evaluation of environmental impacts associated to different ELT management strategies and of different paving technologies (of the standard and non-standard type);
- Action 2.6, which analysed the local context of the project in terms of its potential involvement in future activities related to the use of recycled materials in road construction.

Finally, a significant contribution to the success of the TYREC4LIFE project originated from Action 5, which was entirely dedicated to the evaluation of the considered innovative paving technologies in terms of their effective environmental impact and of the effects which they may have on the health of working crews.

Key deliverables which were prepared as a consequence of the above listed actions were the following:

- State-of-the-art reports on ELV and ELT management (Action 2.1), available aggregates (Action 2.4) and available crumb rubber products (Action 2.5);
- Evaluation reports on environmental impacts of different ELT management options (Action 2.2), environmental impacts of different paving technologies (Action 2.3) and activities, products and recycling materials at short supply distance (Action 2.6);
- Technical reports on laboratory investigations performed for the characterization of asphalt rubber binders (Action 3.1) and bituminous mixtures containing crumb rubber (Action 3.2);
- Technical specifications for the mix design and quality assurance of bituminous mixtures containing crumb rubber ("wet" technology) (Action 3.2);
- Guidelines for the field implementation of the "wet" technology (Action 3.6) and of the "dry" technology (Action 3.5), including the use of viscosity-reduction additives (Action 3.4);
- Site monitoring reports of full-scale paving sections (Actions 4.1 and 4.2);
- Life Cycle Risk Assessment model (Action 5);
- 9 Papers published in technical and scientific journals and in Conference proceedings (Action 6.8.2);
- 4 Technical publications (Technical Briefs) prepared for Contractors and Administrations (Actions 6.8.3 and 6.8.4);
- A Report on benefit Assessment of Project's Profitability (BAPP) (Action 6.8.5);
- A Layman's Report (Action 6.9).

Physical outputs of the TYREC4LIFE project, which will be further exploited in its after-life, are the following:

- A new full-scale prototype for the implementation of the "dry" technology, fully available for further experimental investigations;
- Approximately 42,000 $m^2$ of pavements with wearing courses containing asphalt rubber binders (thickness 3 cm) and 2,000 $m^2$ of two-layer pavements (total thickness 8 cm) constituted by bituminous mixtures produced by means of the

abovementioned prototype device, all available for future monitoring under the effects of traffic loading and environmental factors.

This Report was prepared after completion of the TYREC4LIFE project with the contribution of all partners.

# 2. Introduction

Every year in the European Union approximately 3.2 million tonnes of used tyres are generated, of which 2.5 million tonnes are either recycled or recovered (data from ETRMA, European Tyre & Rubber Manufacturers' Association). As indicated by European Law 1999/31/CE, end-of-life tyres (ELTs) cannot be landfilled since they have a lower heating value (LHV) which is higher than the maximum acceptable limit, set at 13,000 kJ/kg. As a consequence of such a limitation, nowadays the most frequent fate of ELTs is energy and matter recovery. However, the current management scenario of ELTs is bound to change in the near future since from 2015, according to another European Law (2000/53/CE), at least 95% b.w. of each end-of-life vehicle will have to be recycled/recovered. The study of new alternatives for matter recovery from ELTs is therefore fundamental and requires more research.

Past studies and experience proved that crumb rubber derived by size-reduction from ELTs may be used in paving applications as an additional component of bituminous mixtures. In particular, its inclusion in such materials can be obtained by means of two different production methods, indicated as the “wet” and “dry” processes, with the consequent construction of high-performance pavement layers. Such a solution constitutes a widely accepted standard in some Countries (e.g. several States in USA, Portugal, Spain), but has been adopted only in exceptional cases, mainly within research and development projects, elsewhere. In the specific case of Italy, full-scale applications have been limited and as a consequence of the lack of experience Administrations have not yet included crumb rubber -based technologies in their standard Technical Specifications.

As a consequence of the scenario outlined above, the TYREC4LIFE project was conceived and thereafter proposed for funding to the European Commission in order to develop and implement innovative technologies with the potential of expanding the use of scrap tyre rubber in road pavements. In particular, the following four objectives were set:

- Objective n. 1: Validation of the use of bituminous mixtures with alternative formulations;
- Objective n. 2: Evaluation of the potential use of reduced-quality or recycled aggregates;
- Objective n. 3: Development of solutions for the reduction of energy consumption and emissions;
- Objective n. 4: Preliminary implementation of the “dry” technology.

To reach these objectives, analyses and investigations were carried out through office work, in the laboratory and on site by adopting a multi-disciplinary approach with contributions from different areas of engineering (pavement and sanitary-environmental) and the involvement of partners of different types (Administrations, Contractors, private and public research Institutions). Finally, the full-scale construction of a production prototype device and of road pavement sections were the project’s assets which provided its tangible and time-lasting output.

Within the LIFE+ program, the TYREC4LIFE project was centred in the field of “Environment Policy and Governance” and more specifically had a demonstration and innovation character related to the priority area of action n. 9 “Waste and Natural Resources”.

# 3. Administrative part

## 3.1. Description of the management system

In this paragraph an overview on the project's implementation main phases and consequent contractual adjustments is given. Then an account on roles and responsibilities of the partners follows. The methodology ad organisation of the management process is finally described

**Phase 1 - Project Start September 2011**. The project implementation started in September 2011, specifically concerning the project management performed by the Coordinating Beneficiary and the partner Ceipiemonte. The other partners started their activity in October 2011. Each Beneficiary has appointed its project responsible and its project team. The Coordinating Beneficiary has received from each project partner a communication concerning the staff assigned to the project and relevant information concerning project work setting, especially on: due records of project incomes and expenses, registration of staff time spent on project activities, TVA.

**Phase 2 – From start to Inception Report May 2012**. On that date the project objectives and the work plan was still viable and all the activities scheduled are on time. Only the action 2.4 (Evaluation of current status of aggregates standard and recycled available for bituminous mixtures containing scrap tyre rubber) was delayed, because the incenerator on that date was not available.

The inception report was submitted regularly in May 2012, covering the inception period from 01/09/2011 to 31/03/2012 (7 months).

**Phase 3 – From Inception report (May 2012) to Amendment I - July 2013**. The First Amendment Request was presented in July 2013 as there had been important and significant events that required a modification of the proposal in order to safeguard the achievement of objectives. In particular:

- a beneficiary – ASM - had undergone the winding-up (liquidation) procedure in 2012. Since August 2012, with formal deed, the business unit, the activities and related contracts in place (including the LIFE10ENV/IT/000390 - Tyrec4life project) had been leased to "Patrimonio Città di Settimo Torinese srl Sole Proprietorship". "Patrimonio Città di Settimo Torinese", wholly owned by the Municipality of Settimo Torinese, therefore it replaced ASM;
- the beneficiary Co.Ge.Fa. changed its corporate structure and the new management company formalised a request to withdraw from the project. Actions of Co.Ge.Fa. were taken over and carried out by Brillada;
- from the periodic checks on project progress, the need for an overall improvement of the project was required, in particular "Design of mixing device for dry technology (action 3.3.1)" and "The implementation of a different prototype approach" (action 3.3.2 - Development of a full scale prototype mixing device for the implementation of "dry" technology). A more flexible prototype with a better performance was proposed and subsequently performed. This made necessary to make changes to the initial budget.

These requests were included also an extension of the project duration until 31 December 2014. The request was submitted in July 2013 and approved in February 2014.

**Phase 4 – until submission of Mid Term Report in February 2014 covering the period 01/04/2012 – 30/09/2013**.

**Phase 5 – From 01/10/2013 to 31/12/2014**: In the last year, several significant changes to the corporate structure of the project beneficiaries have taken place and a request for general improvement of the approved project has been formalised. At that time there had been no other problems and activities proceeded according to the new time schedule defined in the change request.

Nevertheless, **a** second Amendment was presented in September of 2014 as a result of a number of administrative problems concerning the paving works assigned to the Province of Turin and Patrimonio Città di Settimo Torinese. These recorded significant delays because of the bidding procedures ond of the constraints imposed by the Growth and Stability Pact. It became evident that the scheduled deadline for the completion of the works within December 2014 could not be met.

This made necessary the request for the second amendment of the contract, concerning one further postponement of the implementation deadline until 30/09/2015.

**Phase 6 – Closure Phase.**

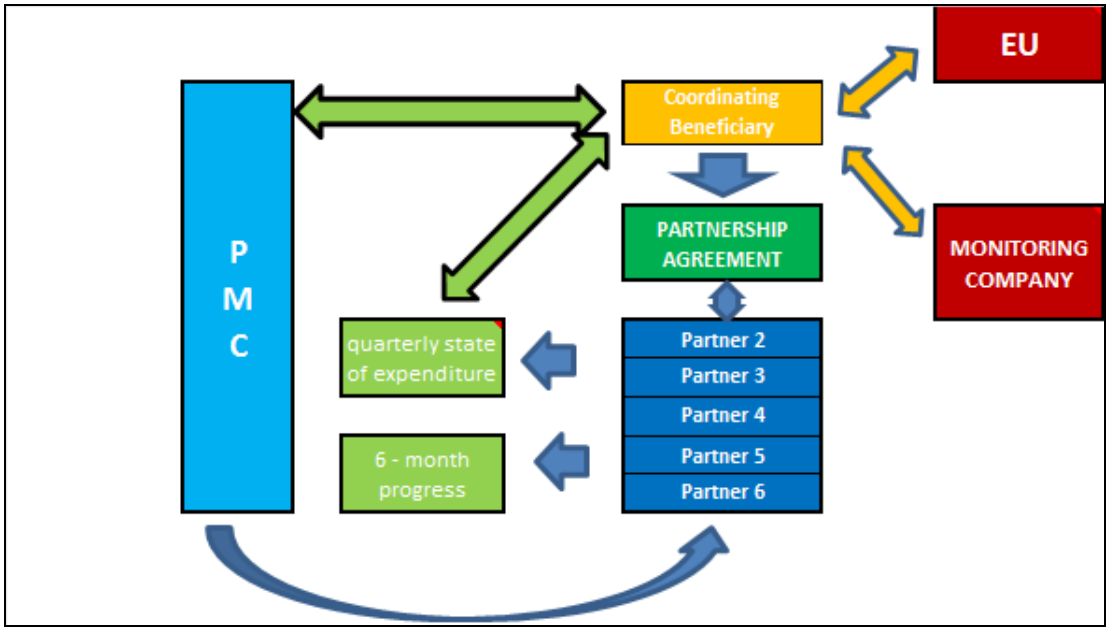
The second interim report was submitted (covering the period 01/10/2013 – 31/12/2014).

The amendment number 2 (closure date set as of 30/09/2015) was formalized.

Several administrative issues have arisen mainly as a result of unpredictable constraints in bidding procedures and financial restraints caused by the "Stability Act" imposed on Italian Local Authorities and for this reason action 4.1 was postponed, and subsequently completed. The partner "Società Patrimonio di Settimo Torinese" originally planned that it would appoint a Contractor for paving works through direct negotiation. However, considering the local elections in Settimo Torinese that resulted in the change of the administrative body in May 2014, the decision to quit the direct treaty procedure and to adopt a bidding procedure was taken. The action was definitely completed in July 2015.

Final Project conference was successfully held in September 2015.

The management of the project is presented below.

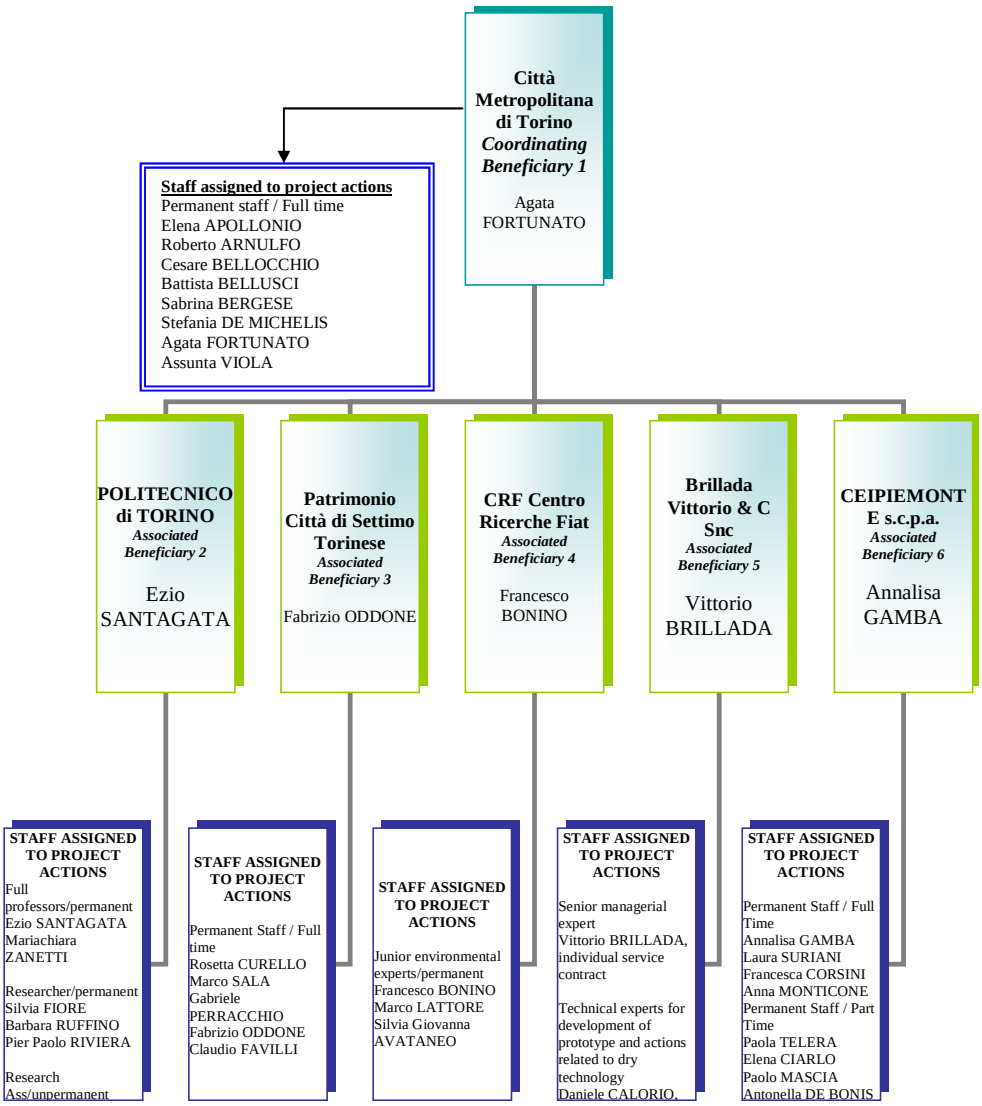


The coordinating Beneficiary is the sole responsible of the implementation of the project vis-à-vis the Contracting Authority. Obligations are established by means of the Grant Agreement. The Contracting Beneficiary makes clear the responsibilities of the partners via partnership agreements signed by each partner and the Coordinating Beneficiary itself.

As a first formalisation of project monitoring mechanisms, article 11.1 of partnership agreements states that each project partner will provide any relevant information to the Coordinating Beneficiary 45 days before the deadline submitting reports to the Commission. Moreover, the same article states that each partner must be available with additional information, should the Commission requests so.

The beneficiaries under the coordination of the Coordinating beneficiary constitute the Project Management Committee, which is gathered at least three times per year. The committee informs its member on the progress of the project, agrees on technical and financial activities to undertake, sets the working schedules, steers the project activity, if required, according to shortcomings, new issues and new elements that may arise during the implementation.

The figure below depicts the organization and the roles of each partner, including the names of the staff assigned to the action



In the following a brief presentation of the partners and their role in the project.

**The Metropolitan City of Turin**, Piedmont, is an administrative body replacing the former province of Torino. It was established officially on January 1st 2015 and gathers 315 municipalities, with a population of over 2.3 million inhabitants, covering over 6,800 square kilometres. Its mission includes spatial and environmental monitoring planning and possesses special competence over collection, treatment and disposal of waste. It is also responsible for the management of over 3.000 kms of roads. The Metropolitan City of Turin was the coordinating beneficiary of TYREC4LIFE and made its roads assets available as test fields for the project. The Project was born as a prosecution of the experiences carried out with the Politecnico di Torino in the paving works of one stretch of the ring road Borgaro-Venaria with modified asphalts.

**The Politecnico di Torino**, founded in 1906 from the roots of the Technical School for Engineers, is an excellence hub, centre of teaching and research in all fields of Engineering. With specific reference to the TYREC4LIFE project field of interest, the Polytechnic University of Turin is involved in researches, carried out in collaboration with other universities and public or private institutions, as well as with various European Community bodies relating to the use of rubber dust in road paving, cold recycling of bituminous mixtures, survey on incineration ashes, Life Cycle Assessment (LCA), risk analysis, and the possibility to use rubber and inert waste material coming form different sources for the composition of new bituminous mixtures.

The mission of "**Patrimonio Città di Settimo Torinese S.R.L**" is to implement a coordinated and unified administrative action for the efficient, effective and financially sound management of the environmental and spatial policies of the city of Settimo. As regards TYREC4LIFE, the company performed a survey for the collection of raw waste material from local factories and businesses. This survey was functional to the implementation of the new technologies tested by the project. Moreover, the partner was in charge of a test paving session over a 2-km long stretch on the road network of Settimo Torinese.

**Fiat S.C.p.A Research Centre (CRF)** was founded in 1978 as a focal point for innovation, research and development in the framework of the Fiat Group. Today it is an internationally recognized centre of excellence whose mission is to use innovation as a strategic lever within the group, improving performance through the development and transfer of innovative content. CRF has carried out a series of activities for several years to improve the management of end-of-life vehicles, in addition to the analysis of the best technologies to increase the amount of materials to be sent to recycling for the production of energy. In TYREC4LIFE it has collected data and delivered reports on the environmental impact deriving from the use of tyre rubber in asphalts.

**BRILLADA VITTORIO & C Snc** is a company based in Borgaro Torinese (Turin), which has been engaged in the construction and road maintenance since the early '50s. it is actively dedicated to the study and production of bituminous conglomerates for any kind of road construction. For TYREC4LIFE the company has tested the technologies of production of modified asphalts with rubber and was in charge of the creation of a prototype for the production of bituminous conglomerates using the “dry” technology.

**Centro Estero per l’Internazionalizzazione del Piemonte** (Ceipiemonte) is a joint stock non-profit consortium company born in 2006 thanks to the initiative of the Piedmont Region and of the Regional Union of the Chambers of Commerce (Unioncamere Piemonte), together with representatives of economic categories, universities, the Polytechnic University of Turin and other local authorities. While promoting excellence in the world and fostering the internationalization of the area, Ceipiemonte pursues the objectives of strengthening the presence of local businesses, local heritage and local excellences across the world in manifold strategic sectors: Automotive, Aero-Spatial industry, ICT, Constructions, Environment and Biotechnologies. For TYREC4LIFE it had an operational role in the coordination and monitoring of the project implementation.

The setup of the management system was aimed at ensuring the project success through management and coordination. The principles of the management system are:

- Ongoing evaluation of project development
- Ensuring effective coordination and collaboration among all the partners
- Facilitating and ensuring the fulfilment of the project's objectives, in compliance with the agreed time planning and budget/administrative constraints
- Representing the project team in its relations with the European Commission
- Provide exhaustive reporting and useful data on project activity

This task was accomplished through the following tools:

- Definition of the Project Management Committee (PMC) composition and tasks
- Definition of monitoring procedure to evaluate project development (action 8)
- Agreement on working methodology to facilitate communication and interactions
- Set up of periodically review meetings within the project team
- Coordination of quality timely completion and collection of activity deliverables

Project Management is performed by the Coordinating Beneficiary Città Metropolitana di Torino, in terms of global coordination on the whole project. It represents the whole project team in the relations with the European Commission, particularly with the project manager identified for the TYREC4LIFE project, and with the external monitoring team.

A **Project Management Committee (PMC)** has been established during the first partner meeting held on 11/10/2011. It is composed by one representative for each partner who is responsible for taking main decisions during the project and for project management and monitoring of their specific activities.

To ensure effective coordination and collaboration among all the partners, the Città Metropolitana di Torino has established that each partner should prepare a **state of expenditure every 3 months detailed per partner, budget item and action**. To respect this task, each associated beneficiary has to submit to the Coordinating Beneficiary: staff time sheets duly dated and signed, invoices, cost statements.

With this purpose a database for the progressive monitoring of expenditures was implemented. Through this also the monitoring of the actual progress of the project activities has been implemented.

The Commission, as underlined in the letter sent after the fourth monitoring visit, deemed the monitoring activity performed until that moment as not satisfying enough. The project coordinator has therefore developed a new monitoring tool comprising a six-month action fiche, to be filled out for each action..

The 3-month expenditure progress is complemented by a **6-month monitoring sheet** with the technical and financial description of the project progress, both for the ongoing 6-month term and for the cumulated previous terms. Aim of this is to detect delays and gaps and adopt corrective measures. Such measures are normally discussed within the PMC. In the fiche the progress of every single action is monitored carefully and the corresponding expenditure is indicated.

The meeting and interaction with project partners, anyway, did not follow only the official pathway of PMC meetings. There were plenty of occasions where the coordinator could meet the project partners and discuss with them the relevant issues at that moment. At the same time, the delivery of results, reports, deliverables followed after the completion of corresponding activities. The issues, of course, were then brought into the PMC.

The regular checks performed by the external monitoring company proved to be very fruitful. The comments received especially in the first two years helped the partnership improve its management and think more and more intensely in terms of achievement of sustainable and durable results. The partners were always actively involved in the adoption of the measures needed to amend the shortcomings detected by the monitoring visits.

# 4. Technical part

## 4.1. Technical progress, per task

The engineering starting point of the TYREC4LIFE project at the local scale was constituted by the results of previous investigation and implementation activities carried out since 2008 by the Città Metropolitana di Torino and by the Politecnico di Torino on the possibility of employing bituminous mixtures containing scrap tyre rubber for the maintenance of the local road network. In particular, tentative applications considered the use of the so-called "wet" technology, by means of which finely ground tyre rubber (with maximum particle size typically smaller than 1 mm) is pre-mixed with bitumen, thus leading to the production of a ductile and elastic binder, known as asphalt rubber. Moreover, in full coherency with available literature, mixture composition was defined by referring to the classical "gap-graded" formulation (characterized by a non-continuous distribution of aggregate particle sizes and by high filler and binder contents), which has been reported to yield a satisfactory field performance both from a structural and functional viewpoint.

By taking into account the experience and results synthesized above, the following four main technical objectives were set for the TYREC4LIFE project:

**Objective n. 1: Validation of the use of bituminous mixtures with alternative formulation**

Although it was recognized that encouraging results were obtained with the use of gap-graded mixtures, it was deemed necessary to expand the possibilities of use of bituminous mixtures containing asphalt rubber binders. Thus, it was established that the project would consider a wider array of mixtures obtained by changing maximum aggregate size, continuity of aggregate size distribution and target voids content.

**Objective n. 2: Evaluation of the potential use of reduced-quality or recycled aggregates**

One of the issues which was judged to be critical for the widespread acceptance and diffusion of scrap tyre -based technologies was that of aggregate quality, which is generally required to meet very high standards for the formation of bituminous mixtures (of any type, including gap-graded and open-graded). Thus one of the objectives of the TYREC4LIFE project was to consider the potential use of aggregates of different sources and types (including recycled products) in order to overcome limitations due to the local availability of premium quality aggregates and/or for the reduction of overall construction and maintenance costs. In such a context, it was planned that investigations would be carried out on mixtures prepared by employing (local) standard aggregates, recycled asphalt pavement (RAP) material and incineration ashes coming from the newly constructed waste incinerator of the City of Turin.

**Objective n. 3: Development of solutions for the reduction of energy consumption and emissions**

It is well known that due to the high viscosity of asphalt rubber, production and laying of the corresponding bituminous mixtures (of any type) is generally carried out at temperatures which are higher than those of standard mixtures. This leads to an overall environmental impact scenario characterized by higher energy consumption (and costs) and greater release of gaseous emissions which may affect the health of working crews.

Moreover, the construction season of these mixtures is typically shortened due to their higher sensitivity to environmental temperature. As a consequence of these problems, which prevent the widespread diffusion of asphalt rubber mixtures, one of the main objectives of the TYREC4LIFE project was to identify and implement technological solutions which may decrease binder viscosity. Investigations were planned in the laboratory and in the field in order to fully understand the effects of viscosity-reduction additives and to assess their effectiveness in reduced-scale paving trials. Activities related to the use of viscosity-reduction additives were also carried out in Actions related to Objective n. 4, focused on the preliminary implementation of the "dry" technology.

**Objective n. 4: Preliminary implementation of the "dry" technology**

Notwithstanding the fact that in literature it is clearly indicated that the "wet" technology has proven to be extremely reliable for the construction and maintenance of highly-performing pavements, a further objective of the TYREC4LIFE project was that of exploring the possibility of implementing at a full-scale level the alternative "dry" technology. In this case scrap tyre rubber is directly added in the mixer of the hot mix plant in partial substitution of fine aggregates, with the possibility of employing rubber quantities which are typically greater than those of used in the "wet" process. In such a context it should be considered that bituminous mixtures deriving from the "dry" technology have yielded an inconsistent performance record, with Contractors often reporting non negligible problems related to homogeneity and compaction which can promote early ravelling phenomena and moisture-related damage. Within the project it was therefore envisioned to develop a specific prototype device for the preliminary implementation of the "dry" technology, to be validated by means of laboratory tests and reduced-scale field trials.

The technical activities necessary to reach the objectives described above were structured in Actions which were grouped as indicated in the following:

- Action 2 - Evaluation: with the goal of defining the operative context of the project, validating its relevance and preventively evaluating the possibility of consequent implementations;
- Action 3 - Experimental investigations and technological development: with the goal of directly developing the technological and scientific bases on which to found implementation activities;
- Action 4 - Implementation: with the goal of giving the project its required demonstrative character;
- Action 5 - Life Cycle Risk Assessment: with the goal of globally evaluating the sustainability of the technologies considered during the project in terms of potential impacts on the environment and on the health of construction workers.

Individual actions included in each of the groups listed above are described in the following paragraphs. As per LIFE+ requirements, "project management" tasks (Action 1) and "dissemination" tasks (Action 6), which also contributed to the progress of the project, are illustrated in other sections of the Report (4 and 5.2, respectively).

## ACTION 2: EVALUATION ACTIONS

### Action 2.1. Evaluation of the current status of the recycling / energy recovery of End-of-Life Tyres (ELTs) and End-of-Life Vehicles (ELVs) in order to achieve European targets

Beneficiary responsible for implementation of the Action:

Centro Ricerche Fiat (CRF)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | × | × | × | × | | | | | | | | | | | | | |
| 1st Amendment | | × | × | × | × | | | | | | | | | | | | | |
| 2nd Amendment | | × | × | × | × | | | | | | | | | | | | | |
| Effective | | • | • | • | • | | | | | | | | | | | | | |

Description:

Action 2.1 was included in the TYREC4LIFE project as part of its preliminary evaluation phase in order to set the context, at the national and international scale, within which the issue of end-of-life tyres (ELTs) is addressed. In particular, the goal of the Action was to describe the current status of recovery, reuse and recycling with respect to the implementation of the so-called European Directive, which refers to the more general problem of efficiently managing end-of-life vehicles (EVTs).

Analyses carried out in Action 2.1 were based on data and documents retrieved from literature and on the information gathered through technical visits and meetings with representatives of the various components of the ELV/ELT management chain (dealers, dismantlers, crushers, shredders, companies in charge of energy recovery, organizations coordinating scrap tyre collection).

Investigations were performed by the Beneficiary of the Action (Centro Ricerche Fiat, CRF) with the cooperation of Ecopneus scpa. No major problem was encountered in any phase of the Action.

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project):

- The Italian ELV management, based on the close cooperation of Government, Industry and Sector Associations, proved to be successful in reaching European recycling and recovery 2006 targets (80% reuse and recycling; 85% reuse and recovery);
- Strategies for the maximization of ELV recycling and recovery, necessary in order to reach the 2015 targets (85% reuse and recycling; 95% reuse and recovery), are mainly related to the increase of post-shredding for the separation of material flows and will be supported by dedicated projects (e.g. TARGET FLUFF project);
- Data retrieved from the Eurostat database indicate that the European scenario is characterized by a significant variability, although the efforts of most Countries in trying to fulfil the 2015 targets are clearly proven by positive trends;
- The new Italian ELT collection and management system, based on the “producer responsibility” principle and on the imposition of an environmental fee on tyre

sales, in its initial implementation led to very encouraging results (approximately 73,000 tons of collected and treated ELTs in 2011);

- Data taken from reports issued by ETRMA (European Tyre and Rubber Manufacturers' Association) and IRSG (International Rubber Study Group) indicate that the percentage of collected tyres is constantly increasing, approaching the 95% threshold in 2011;
- Currently available options for ELT recycling cover a wide range of possible applications which are widely documented in literature;
- ELT recycling technologies related to the construction of road pavements have attracted the attention of Administrations and researchers both at the national and international level, although their introduction in the Italian context as of 2012 was still in a very preliminary phase;
- ELT energy recovery technologies have been more easily implemented into practice as a result of the high calorific value of rubber and may be considered as standard options available to the Industry (e.g. in cement kilns and thermoelectric power stations);
- Due to the fact that tyres represent approximately 3% of the weight of a whole vehicle, ELT recycling and recovery are among the key strategic activities which should be enhanced and sustained in order to reach the 2015 European targets.

Action 2.1 was successfully completed within the planned timeframe.

**Action 2.2. Environmental evaluation of recycling technologies of crumb rubber from ELTs in comparison with solutions such as landfill disposal and energy recovery**

Beneficiary responsible for implementation of the Action:

Centro Ricerche Fiat (CRF)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
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Description:

Action 2.2 of the TYREC4LIFE project focused on the assessment of the overall environmental impact associated to the possible destinations of end-of-life tyres (ELTs). In particular, the purpose of such an evaluation was to highlight the potential benefits produced by recycling activities.

ELT management options which were subjected to analysis included mechanical pulverization processes (MPP), substitution of conventional fuel in cement kilns and landfill disposal. Such processes were compared by means of a Life Cycle Assessment (LCA) methodology in accordance with ISO 14040 and ISO 14044, thus taking into account both direct and indirect environmental effects. By referring to a common function unit of 1 ton of ELTs, the LCA study was carried out by making use of the GaBi v.6 software and by retrieving data for the Life Cycle Inventory (LCI) from available literature and from companies contacted during the course of Action 2.1.

Results were expressed in terms of several parameters, the two main ones being Global Warming Potential (GWP) and Primary Energy Demand from renewable and non-renewable resources (PED), which are reliable indicators of greenhouse emissions and life cycle energy consumption, respectively.

Investigations were performed by the Beneficiary of the Action (Centro Ricerche Fiat, CRF). No major problem was encountered in any phase of the Action.

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project):

- As expected, landfilling constitutes the worse environmental scenario in terms of both GWP and PED, while use in cement kilns leads to an environmental profile which is the best in terms of PED since it is associated to a significant reduction of fossil fuel consumption and to the possible recovery of metal;
- Mechanical pulverization is by far the best option in terms of GWP due to the fact that it allows recycling of rubber and metal, but its environmental profile may be further enhanced by fine-tuning production processes in order to obtain distributions of rubber particle sizes more compatible with subsequent recycling processes.

Action 2.2 was successfully completed within the planned timeframe.

**Action 2.3. Environmental evaluation of the use of crumb rubber from ELTs in road paving technologies in comparison with standard solutions**

Beneficiary responsible for implementation of the Action:

Centro Ricerche Fiat (CRF)
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | | × | × | × | × | × | × | | | | | |
| 1st Amendment | | | | | | | | × | × | × | × | × | × | | | | | |
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Description:

Action 2.3 of the TYREC4LIFE project considered the overall environmental impact associated to various paving technologies, with the primary goal of highlighting the potential benefits deriving from the production and use of bituminous mixtures containing crumb rubber from end-of-life tyres (ELTs). Given the preparatory character of the Action, evaluations were intended to be based on data retrieved from literature, while environmental assessment of the paving works performed during the implementation phase of the project (Actions 4.1 and 4.2) were planned as part of Action 5.

Paving technologies considered in the study of Action 2.3 were those which may be employed, within new construction and rehabilitation projects, for the formation of wearing course layers. In particular, options subjected to analysis were those of standard (reference) dense-graded bituminous mixtures, gap-graded and open-graded bituminous mixtures containing asphalt rubber (produced by means of the "wet" process) and bituminous mixtures produced by means of the "dry" technology (in which crumb rubber is directly added to the other components in the plant mixer).

Comparisons were performed by means of a Life Cycle Assessment (LCA) methodology in accordance with ISO 14040 and ISO 14044. Adopted functional units were constituted by a wearing course covering a surface of 1 km in length and 4 m in width, with variable thickness depending upon the considered technology. Calculations were based on the use of the GaBi v.6 software, while the Life Cycle Inventory (LCI) stemmed from the Eurobitume database and from experimental investigations carried out on paving trial sections by the Politecnico di Torino as part of other research projects.

As for Action 2.2, results were expressed in terms of several parameters, the two main ones being Global Warming Potential (GWP) and Primary Energy Demand from renewable and non-renewable resources (PED), which are reliable indicators of greenhouse emissions and life cycle energy consumption, respectively.

Investigations were performed by the Beneficiary of the Action (Centro Ricerche Fiat, CRF) with the cooperation of the Politecnico di Torino. No major problem was encountered in any phase of the Action.

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project):

- As expected, in comparison with standard paving solutions, significant environmental benefits were identified in the case of those options involving the use of innovative bituminous mixtures containing crumb rubber from ELTs;
- The “dry” paving technology yielded results which were comparable to those of standard solutions, due to similarities in terms of percentage of bitumen, total quantity of mixture and design wearing course thickness;
- Significant benefits were found in the case of paving solutions based on the use of asphalt rubber as a binder (“wet” technology), especially in the case of gap-graded mixtures, since they allow a reduction of wearing course thickness;
- Further environmental advantages associated to the use of bituminous mixtures containing crumb rubber, which are expected to exhibit a higher durability in service, may be highlighted by extending the analyses beyond the boundaries set in the present study (which focused on production and laying) so to include the use and maintenance phases.

Action 2.3 was successfully completed within the planned timeframe.

**Action 2.4. Evaluation of the current status of aggregates available for bituminous mixtures containing crumb rubber**

Beneficiary responsible for implementation of the Action:

Politecnico di Torino

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
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Description:

In the TYREC4LIFE project proposal it was stated that Action 2.4 would consider the availability of aggregates for bituminous mixtures containing crumb rubber from ELTs, mainly focusing on those coming from quarries in the Piedmont region. Furthermore, the assessment was meant to be extended to innovative/recycled materials, such as incinerator bottom ashes, which may contribute to the reduction of the overall environmental impact of pavement construction activities.

While activities related to the evaluation of standard aggregates were completed within the predicted timeframe, delays occurred in the characterization of innovative/recycled aggregates. These were due to the fact that the onset of operations of the new incinerator of the City of Torino was repeatedly postponed (until September 2013), with the consequent impossibility of obtaining bottom ashes. Nevertheless, as described in the following, the Action was successfully completed and yielded very interesting results both for traditional and innovative aggregates.

The initial phase of the Action involved the analysis of available technical data provided by quarries and of the historical databases of the Regional Authority and of the Politecnico di Torino. Data were available on coarse (15/30 mm), intermediate (8/15 mm) and fine (0.2-0.3 mm) fractions, and were expressed in terms of lithological composition, mineralogical composition and resistance to fragmentation (Los Angeles test).

Given the characteristics of available aggregates, two primary sources were identified and the corresponding fractions produced by the quarries were sampled and thereafter employed for laboratory testing. In particular, they were employed for the preparation of reference gap-graded mixtures with 8.0% asphalt rubber binder which were evaluated with respect to their volumetric characteristics (Marshall and gyratory compacted specimens) and mechanical properties (by means of standard, routine tests).

In synthesis (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project) it was concluded that locally available aggregates are adequate for use in gap-graded mixtures containing asphalt rubber binders since requirements set by available Technical Standards on volumetric and mechanical characteristics are fully satisfied.

A similar approach was followed in the case of the bottom ashes coming from the incinerator of the City of Torino. In synthesis the following conclusions were drawn (for details, see the Report provided in attachment):

- Bottom ashes from the waste incinerator of the City of Torino may be used in gap-graded mixtures with aggregate substitution percentages of the order of 20%;
- Due to the high surface area of ashes (which absorb a large amount of bitumen), optimal binder content tends to increase by 0.5% with respect to standard gap-graded bituminous mixtures;
- Use of bottom ashes in gap-graded mixtures leads to an increase of Marshall stability as a result of the variation of internal structure;
- Stiffness, as expressed by the Marshall quotient, seems not to be affected by the presence of bottom ashes.

Experimental investigations on mixtures prepared both with standard and innovative/recycled aggregates were performed in the Road Materials Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

Action 2.4 was successfully completed within the end of the TYREC4LIFE project.

**Action 2.5. Evaluation of the current status of the crumb rubber availability in Italy**

Beneficiary responsible for implementation of the Action:

Politecnico di Torino

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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Description:

Action 2.5 was included in the TYREC4LIFE project in order to assess the availability status of crumb rubber in Italy, with a special interest in those products which can be used as additional components in bituminous mixtures for paving applications. The evaluation was scheduled to be based on the analysis of existing data, on the observations derived from technical visits to ELT treatment plants and on the results obtained in dedicated laboratory investigations.

The six treatment plants which were subjected to evaluation, distributed in the entire Italian territory, were selected among those which operate with continuity according to well-defined production processes at ambient temperature. For comparative purposes, an additional cryogenic plant, located in Portugal, was also included in the study.

Plant configurations were found to be quite variable and were described by referring to the exact sequence of the various phases of shredding, iron magnetic separation, milling and sieving. In general terms it was recorded that production processes were dependent upon the actual inflow of material and on the desired quality of end products. According to owners, managers and operators, all the considered plants employed both car and truck tyres, with the only one exception (where processed ELTs came only from heavy vehicles).

Crumb rubber samples were taken from all treatment plants and were subjected to laboratory tests for the determination of particle size distribution and evaluation of content of heavy metals, PAH (polynuclear aromatic hydrocarbons), BTEX (benzene, toluene, ethylbenzene and xylene) and elemental analysis. Additional tests were performed on bituminous mixtures for the assessment of the effects caused by crumb rubber (included as part of asphalt rubber binder) in leaching phenomena.

Investigations were performed in the Environmental Chemistry Laboratory and in the Road Materials Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

In synthesis the following conclusions were drawn (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project):

- Based on the combined analysis of available technical information and experimental data, it was possible to find relationships between the type of plant treatment and crumb rubber physical and chemical properties;

- Significant variations in particle size distribution were found as a result of the differences in the production processes;
- Heavy metals were found to be within expected ranges, with the lower values presumably associated to a more efficient selection of materials;
- Elemental analysis gave results which were quite uniform for all plants, thus revealing that the average composition of processed tyres is indeed constant (with higher carbon content values probably associated to the additional processing of non-vulcanized rubber coming from alternative sources);
- BTEX and PAH values were found to be extremely variable, the lower values being associated to the processing of truck tyres only (with a higher percentage of natural rubber with a low content of organic aromatic substances);
- The cryogenic treatment, not available in Italy at the time of the investigation, led to high PAH values, probably due to the fact that the low-temperature treatment does not allow volatilization of organic substances to take place to the same extent of ambient processing;
- Results of leaching tests showed that bituminous mixtures containing crumb rubber may have an enhanced environmental compatibility with respect to PAH and BTEX release.

Action 2.5 was successfully completed within the planned timeframe.

Obtained results were compounded in a database which is constantly being updated as more research work on crumb rubber products is being performed by the group of the Politecnico di Torino. Thus, the Action is naturally being extended beyond the time limits of the TYREC4LIFE project and will hopefully lead to a deeper understanding of the characteristics of crumb rubber products for paving applications.

**Action 2.6. Screening for alternative material at short supply distance**

Beneficiary responsible for implementation of the Action:

Patrimonio Città di Settimo Torinese

Planning and progress of the Action:

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Description:

In the TYREC4LIFE project the set of evaluation Actions was completed by Action 2.6, the function of which was to provide updated information on the production and commercial activities which can be potentially involved at the local scale in recycling-related technologies. These were to include not only rubber-based materials, but all those which can be of interest for innovative road paving applications.

Delays in the progress of the Action occurred as a consequence of the partner change, Patrimonio Città di Settimo Torinese replacing ASM, which entailed a complete interruption of activities between May and September 2012. Nevertheless, as described in the following, the Action was successfully completed.

Analyses were carried out by considering local manufacturers and traders involved in activities corresponding to ATECO codes (attributed by the Italian National Institute of Statistics, ISTAT) 38.32.20 (Recovery and preparation for recycling of plastic materials), 38.32.30 (Recovery and preparation for recycling of urban solid waste, industrial waste and biomass) and 42.11.00 (Construction of roads, motorways and airport runways). A profile was prepared for each company with a description of prevailing business, product data sheets and information on willingness to innovate production processes with respect to technical specifications resulting from the TYREC4LIFE research project.

The search initially included approximately 100 businesses located in the Province of Torino, but it was subsequently reduced to encompass those located within a distance of 30 km from the City of Settimo Torinese. Such a choice was made to lay the foundations for the formation of an enhanced local recycling chain in which transportation costs and consequent environmental impacts would be minimized.

All the gathered information was compounded in a geo-referenced database implemented into the Territorial Informative System (SIT) of the Municipality of Settimo Torinese. Its main characteristics are described in the Report of the Action, provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project

Investigations and activities related to the development of the database were performed by the Beneficiary of the Action (Patrimonio Città di Settimo Torinese). No major problem was encountered in any phase of the Action.

Action 2.6 was successfully completed within the end of the TYREC4LIFE project.

## ACTION 3: EXPERIMENTAL INVESTIGATION AND TECHNOLOGY DEVELOPMENT

### Action 3.1. Characterization of asphalt rubber binders

Beneficiary responsible for implementation of the Action:

Politecnico di Torino

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
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Description:

In the TYREC4LIFE project proposal it was clearly stated that Action 3.1 would be of experimental character, focused on the assessment of the rheological properties of asphalt rubber binders. It was pointed out that investigations would consider both standard binders and binders combined with viscosity reduction additives, useful for the reduction of processing temperatures and of the consequent energy consumption and emission of fumes.

In the first phase of the investigation, tests were carried out on bitumen-rubber blends prepared by employing a single reference base bitumen combined with crumb rubber products derived from ambient, cryogenic and high pressure waterjet production processes. Crumb rubber dosage was varied between 5 and 20%. For comparative purposes, the investigation also considered industrial bitumen-rubber blends ("asphalt rubber" binders) containing approximately 18% (by weight on total binder) of crumb rubber. Before preparation of asphalt rubber blends, crumb rubber products were characterized in terms of their density, morphology and surface area.

Asphalt rubber binders were subjected to viscosity tests in a temperature range comprised between 125 and 190°C and obtained were fitted to a power-law model. The entire set of experimental data was subjected to further processing for the identification of the possible relationships between physical and morphological characteristics of crumb rubber and flow properties of corresponding blends. In particular, a quantitative prediction model was developed.

In synthesis the following conclusions were drawn (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project):

- Procedures and models developed for the assessment of crumb rubber morphology were found to be reliable, yielding results which were coherent with the peculiarities of crumb rubber production processes and with general information available in literature;
- It was observed that regardless of the fact that they are composed of smooth and regularly shaped particles, cryogenic crumb rubber products are characterized by a higher surface area due to their finer size distribution;

- Viscosity of the binders containing ambient crumb rubber products was definitely higher than that of asphalt rubber prepared with the same dosage of cryogenic crumb rubber;
- The highest viscosity values were measured for the binder prepared with the ambient crumb rubber derived exclusively from truck tyres, which contains a higher percentage of natural rubber;
- The proposed viscosity-prediction model proved to be statistically sound and coherent with interaction phenomena which occur within asphalt rubber binders.

In the second phase of the investigation, tests were carried out on bitumen-rubber blends prepared by employing three different reference base bitumens combined with a single crumb rubber product derived from ambient production processing. Crumb rubber dosage was set at 18.5% (on total weight of asphalt rubber binder). Additional binders were prepared by employing a commercially available low-viscosity additive (a long-chain aliphatic hydrocarbon wax) with a dosage of 3% by weight on base bitumen.

Viscosity tests were performed at 175°C with the subsequent evaluation of characteristic parameters which describe the time-dependent interaction between rubber particles and base bitumen during mixing.

In synthesis the following conclusions were drawn (for details, see the Report provided in attachment):

- All asphalt rubber binders exhibited a common time-viscosity trend, in which an initial swelling phase I followed by a degradation phase;
- The use of the low-viscosity additive reduces by one-third the time required for the achievement of peak viscosity conditions.

All investigations were performed in the Road Materials Laboratory and in the Environmental Chemistry Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

Action 3.1 was successfully completed within the planned timeframe.

Obtained results were compounded in a database which is constantly being updated as more research work on asphalt rubber binders is being done by the group of the Politecnico di Torino. Thus, the Action is naturally being extended beyond the time limits of the TYREC4LIFE project and will hopefully lead to a deeper understanding of the characteristics of asphalt rubber binders for paving applications.

**Action 3.2. Characterization of bituminous mixtures containing crumb rubber from ELTs**

Beneficiary responsible for implementation of the Action:

Politecnico di Torino

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
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Description:

Action 3.2, which focused on the laboratory characterization of bituminous mixtures containing crumb rubber from ELTs, was deemed necessary in order to gather information on their potential field performance and to provide guidelines for their mix design. Moreover, it was conceived as a preparatory action to implementation Actions 4.1 and 4.2, which were scheduled further on in the project.

By taking into account the results obtained in Actions 2.4 and 2.5, bituminous mixtures were prepared by employing aggregates of different origins and asphalt rubber binders containing several crumb rubber types. Considered mixtures included not only standard gap-graded ones, but also mixtures with alternative formulations (coherently with Objective n. 1 of the project) characterized by a lower binder content, by a coarse aggregate structure or by a continuous size distribution of aggregate particles.

The experimental investigation included the following tests: compaction (Marshall, gyratory and roller), volumetric (theoretical maximum density, percent air voids, voids in the mineral aggregate and voids filled with bitumen), simple QA/QC mechanical (Marshall and indirect tensile strength before and after water immersion), performance-related mechanical (wheel-tracking and semi-circular bending) and environmental (leaching and potential gaseous emission).

Investigations were performed in the Road Materials Laboratory and in the Environmental Chemistry Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

Obtained results (see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project) constitute a valuable reference database for future full-scale applications. Moreover, they were used for the definition of the Technical Specifications which were adopted for the construction of full-scale test sections in Actions 4.1 and 4.2 (provided in attachment and identified as one of the Deliverables of the TYREC4LIFE project).

Technical Specifications, which refer to gap-graded and dense-graded mixtures containing crumb rubber, include:

- Prequalification requirements for component materials;
- Mix design procedures to be adopted for identification of job mix formulae;
- Acceptance procedures which the commencement of permanent works;

- Laying procedures;
- Control plan for quality assurance.

Action 3.2 was successfully completed within the planned timeframe.

## Action 3.3. Development of devices for the implementation of the “dry” technology

### Action 3.3.1. Design of protoype device

Beneficiary responsible for implementation of the Action:

Politecnico di Torino
(Action developed with the cooperation of Brillada Vittorio & C.)

Planning and progress of the Action:

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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
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| 2nd Amendment | | | | | × | × | × | × | × | × | × | | | | | | | |
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Description:

In the TYREC4LIFE project proposal originally approved by the European Commission it was stated that the preliminary implementation of the “dry” technology would require, through Action 3.3.1, the design of a new mixer to be inserted in the production line of a standard hot mix plant. In particular, such a device should have the capability of receiving aggregates preheated in the dryer, scrap tyre rubber and bitumen, operating in appropriate conditions in order to prevent the occurrence of segregation phenomena which are typical for “dry” mixtures prepared in standard mixers (as a result of the significant differences in unit weight between aggregates and crumb rubber).

Design of the prototype was developed by considering available technological solutions (evaluated through analysis of literature and technical visits) and by trying to achieve the maximum flexibility in terms of:

- Mode of introduction of crumb rubber: either “hot”, through premixing with aggregates in the dryer, or “cold”, through direct addition in the mixer, with expected differences in the interaction with other mixture components;
- Type of crumb rubber: ranging from ultrafine to coarse (include the standard “fine” type), in order to affect in different ways the internal structure of “dry” mixtures;
- Quantity of crumb rubber: taking 1% (by weight on dry aggregates) as a reference and by possibly increasing such a quantity if compatible with production constraints.

Design activities were supported by laboratory investigations in which “dry” mixtures were prepared by considering those derived from the factorial combination of mixture type (for wearing and base course), crumb rubber type (ultrafine and coarse) and mode of introduction of crumb rubber (“hot” and “cold” protocol). Laboratory-prepared mixtures were subjected to volumetric and mechanical tests, with an emphasis placed on gyratory compactor parameters, which provide information on the workability of mixtures, and on elastic modulus, considered as a reliable indicator of their structural properties.

Given the width and complexity of the investigation, an extension of the duration of the Action was deemed necessary. This was communicated to the European Commission as part of the first request for amendment request issued on 05/06/2013.

Investigations were performed in the Road Materials Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

Experimental results highlighted the fact that introduction of scrap tyre rubber in bituminous mixtures by means of the "dry" technology causes the following effects (for details, see the Report provided in attachment, identified as one of the deliverables of the TYREC4LIFE project, which includes achievements of Actions 3.3.1, 3.3.2, 3.4 and 3.5):

- volumetric expansion of mixtures after compaction, which is negligible when fine rubber particles are employed and is significant in the case of coarser products (with the consequent need of changing the optimization process);
- increase of the optimal binder content, which is greater when fine rubber particles are used and in the case of rubber use in "cold" conditions (with no pre-heating);
- reduction of workability, which is greater in the case of employment of smaller rubber particles;
- reduction of stiffness, which is greater in the case of use of coarser rubber particles.

In synthesis the following conclusions were drawn:

- mixtures prepared according to the "hot" protocol were superior to the others, thus suggesting that premixing of crumb rubber with aggregates is absolutely necessary to minimize segregation phenomena;
- for all considered crumb rubber types the reference dosage (equal to 1% by weight on dry aggregates) should be recommended, at least in the preliminary phases of full-scale implementation of the technology.

Based on the results and observations listed above, it became clear that the design philosophy of the prototype needed to be changed. Rather than conceiving a new "mixer" it was in fact understood that in order to prevent segregation it was necessary to focus on the premixing of aggregates and crumb rubber. Thus, a new system for the insertion of crumb rubber directly in the dryer should be identified or developed.

The solution which was found to the above described problem was that of employing a double cylinder drum capable of simultaneously processing aggregates and crumb rubber with differential temperature histories. Technical details of this prototype device, together with the final layout of the hot mix plant, are given in the Report provided in attachment.

This new approach to the production of "dry" mixtures led to a modification of the project budget which was one of the subjects of the first request for amendment, sent to the European Commission on 05/06/2013. In particular, higher costs were envisioned as part of Action 3.3.2, reflecting in a reduction of expenditures for Actions 4.1 and 4.2.

Action 3.3.1 was successfully completed within the planned timeframe.

**Action 3.3.2. Development of a full-scale mixing prototype for the implementation of the "dry" technology**

Beneficiary responsible for implementation of the Action:

Brillada Vittorio & C.
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | | | × | × | × | | | | | | | |
| 1st Amendment | | | | | | | | | × | × | × | × | | | | | | |
| 2nd Amendment | | | | | | | | | × | × | × | × | × | × | | | | |
| Effective | | | | | | | | | • | • | • | • | • | • | | | | |

Description:

Action 3.3.2 was entirely dedicated to the full-scale implementation of the prototype device designed in Action 3.3.1. Foreseen activities included construction/installation, calibration and preliminary validation in preparation of the construction of pavement trial sections planned within Action 3.5.

Delays in the construction of the prototype occurred as a result of the change in design philosophy (and of budget) originated by Action 3.3.1 and of the time required for the production and delivery of the selected double drum. Such delays were communicated to the European Commission in the two requests for amendment issued on 05/06/2013 and 29/09/2014. Consequences on the budget of Actions 4.1 and 4.2, which had to be conveniently reduced, were indicated in the first request for amendment.

Installation of the prototype device was performed at the hot mix plant of Brillada Vittorio & C.. The work was carried out by the plant staff with the support of technicians from the supplier (Amman). Picture of these operations are provided in the Report provided in attachment (identified as one of the deliverables of the TYREC4LIFE project, which includes achievements of Actions 3.3.1, 3.3.2, 3.4 and 3.5). No major technical problem was reported in any phase of the Action.

Calibration and verification activities were performed by checking the reliability of the production chain, with a special attention placed on crumb rubber dosage and temperature. Trial mixtures were found to be homogeneous, with no visible sign of segregation. Thus, the production system was approved and considered ready for the scheduled reduced-scale paving trials of Action 3.5.

Action 3.3.2 was successfully completed within the planned timeframe.

**Action 3.4. Solutions for the reduction of energy consumption and emissions in the "dry" recycling technology**

Beneficiary responsible for implementation of the Action:

Brillada Vittorio & C.
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | | | | | × | | | | | | | |
| 1st Amendment | | | | | | | | | | | × | | | | | | | |
| 2nd Amendment | | | | | | | | | | | × | × | × | × | | | | |
| Effective | | | | | | | | | | | • | • | • | • | | | | |

Description:

In the TYREC4LIFE project proposal originally approved by the European Commission it was pointed out that within the preliminary implementation of the "dry" technology it would be advisable to experiment the use of viscosity-reduction additives for the limitation of production costs and of emissions generated during laying operations. Thus, trial mixing activities and laboratory tests were planned for an initial assessment of the produced mixtures.

For these activities it was envisioned that the quantity of produced mixtures would be quite limited (of the order of 10 tonnes), with the corresponding consumption of crumb rubber coming from approximately 50 tyres.

Based on the results obtained from the mix design work carried out on "dry" mixtures in Action 3.3.1, it was decided that Action 3.4 could be changed and expanded in terms of its technical value so to directly assess the properties of mixtures containing viscosity-reduction additives produced by the prototype developed within Actions 3.3.1 and 3.3.2. Thus, Action 3.4 was postponed and scheduled in parallel to Action 3.5. Delays in the finalization of design and construction activities of the prototype (Actions 3.3.1 and 3.3.2) and those due to unfavourable environmental conditions were therefore reflected even on Action 3.4. Nevertheless, as the described in the following, the Action was successfully completed and yielded very interesting results.

The investigation considered a base course mixture containing ultrafine crumb rubber which was produced according to the same job mix formula adopted for one of the mixtures included in Action 3.5, with the additional use of a commercial viscosity-reduction additive (with 1% dosage on the weight of the neat bitumen).

As indicated in the description of Action 3.5, the site selected for the laying of the mixture was within the premises of the plant of Brillada Vittorio & C., close to the prototype itself. As shown in the Report provided in attachment (identified as one of the deliverables of the TYREC4LIFE project, which includes achievements of Actions 3.3.1, 3.3.2, 3.4 and 3.5), the paving surface was equal to 610 $m^2$ with target laying thickness equal to 5 cm.

Production and construction activities were carried out by the Beneficiary of the Action (Brillada Vittorio & C.) between July 2nd and July 6th, 2015. Monitoring activities and subsequent testing were performed by the Politecnico di Torino. No major problem was reported in any phase of the Action.

A brief description of preparatory and laying activities and of sampling operations is provided in the section on Action 3.5. Pictures of paving operations are provided in the Report provided in attachment.

Results obtained on the “warm” mixture, prepared with the viscosity-reduction additive, were compared to those obtained on the other base course mixtures (Action 3.5).

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment):

- No particular problems are registered when using the viscosity-reduction additive in the “dry” production process;
- Use of the viscosity-reduction additive allowed laying to be carried out at a temperature 20°C lower than the one adopted for standard mixtures (130 vs 150°C);
- Volumetric and mechanical properties are not affected by the presence of the viscosity-reduction additive.

From a quantitative point of view, by considering the final extension of the laid mixture and its true composition (and compaction level), it can be concluded that Action 3.4 led to the recycling of approximately 120 tyres. Such a value is significantly higher that the quantity indicated in the project proposal (equal to 50 tyres).

Action 3.4 was successfully completed within the end of the TYREC4LIFE project.

The perspective for continuing the Action after the end of the project is encouraging. In particular, laboratory analyses will focus on the possible use of several other viscosity-reduction additives in order to optimize performance.

It is envisioned that the “warm” version of the “dry” technology may be attractive for Contractors and Administrations as a possible alternative to other technologies based on the recycling of crumb rubber (“wet” and “standard dry”). Thus, other mix design and monitoring activities may be carried out in the future to further support the adoption of such a technology.

**Action 3.5. Trial reduced-scale experimental sections with "dry" technology**

Beneficiary responsible for implementation of the Action:

Brillada Vittorio & C.
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
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| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | | | | | × | | | | | | | |
| 1st Amendment | | | | | | | | | | | × | × | × | | | | | |
| 2nd Amendment | | | | | | | | | | | × | × | × | × | | | | |
| Effective | | | | | | | | | | | • | • | • | • | | | | |

Description:

In the TYREC4LIFE project proposal, it was indicated that in Action 3.5 bituminous mixtures produced according to the "dry" technology by means of the prototype developed in Actions 3.3.1 and 3.3.2 would be laid in reduced-scale sections. The purpose of such activities was on one hand to validate the prototype reliability and on the other hand to provide a preliminary assessment of the functional and structural properties of "dry" mixtures. Moreover, it was envisioned that information could be obtained for possible adjustments of formulation and laying conditions (i.e. temperature and rolling patterns).

Total extension of the trial pavements in the initial project proposal was fixed at 5,000 $m^2$, with a design thickness of 3 cm. In the hypothesis of 5% (by weight of dry aggregates) bitumen content of the laid mixtures and 3% crumb rubber content (in substitution of an equal weight of fine aggregates), this would lead to the recycling of approximately 1,680 tyres (erroneously indicated as 1,725 in the proposal).

Action 3.5 was postponed as a result of the delays in the finalization of design and construction activities of the prototype (Actions 3.3.1 and 3.3.2), and as a result of unfavourable environmental conditions. Nevertheless, as the described in the following, the Action was successfully completed and yielded very interesting results.

Based on the experimental activities carried out during the design phase of the prototype (Action 3.3.1), the technical content of Action 3.5 was significantly expanded so to include not only wearing course mixtures but also base course mixtures. Moreover, it was deemed necessary to explore the possibility of employing both coarse and ultrafine crumb rubber (characterized by particle size ranges equal to 1-4 mm and 0-0.4 mm, respectively).

Mixtures produced and laid on site included the four "dry" ones derived from the factorial combination of layer type and crumb rubber size, plus two additional reference mixtures (for wearing and base courses) included in the activities for comparative purposes.

The site selected for the trials was within the premises of the plant of Brillada Vittorio & C., close to the prototype itself. As shown in the Report provided in attachment (identified as one of the deliverables of the TYREC4LIFE project, which includes achievements of Actions 3.3.1, 3.3.2, 3.4 and 3.5), the total surface covered by paving trials was equal to:

- 2,070 $m^2$ for base course mixtures, with a target laying thickness equal to 5 cm;
- 2,680 $m^2$ for wearing course mixtures, with a target laying thickness equal to 3 cm.

In particular, it was agreed that the individual mixtures would be placed in different areas as indicated in the following:

- The base course mixture containing coarse crumb rubber on 850 $m^2$;
- The base course mixture containing ultrafine crumb rubber on 650 $m^2$;
- The reference base course mixture on 570 $m^2$;
- The wearing course mixture containing coarse crumb rubber on 830 $m^2$;
- The wearing course mixture containing ultrafine crumb rubber on 1050 $m^2$;
- The reference wearing course mixture on 800 $m^2$.

Production and construction activities were carried out by the Beneficiary of the Action (Brillada Vittorio & C.) between July 2nd and July 6th, 2015. Monitoring activities and subsequent testing were performed by the Politecnico di Torino. No major problem was reported in any phase of the Action.

Bituminous mixtures were produced by employing the same base materials (locally available aggregates, standard 50/70 penetration grade bitumen and two types of crumb rubber) previously used for the experimental investigation performed as part of Action 3.3.1. Job mix formulae were also derived from this investigation, focusing only on the recipes defined by referring to the so-called “hot” version of production.

Preparation of the paving site was carried out by the Beneficiary by adequately levelling the surface and by placing an adequate drainage system. Laying of bituminous mixtures was thereafter performed, with the application between the two layers of an emulsion tack coat. Laying was carried out by employing a standard paver, while compaction was thereafter performed by making use of a tandem vibrating roller (Dynapac CC232HF). Pictures of paving operations are provided in the Report provided in attachment.

During laying operations samples of the bituminous mixtures were taken from the paver and thereafter employed in the laboratory for the assessment of their composition and for the evaluation of their volumetric and mechanical properties (following Marshall or gyratory compaction).

Paving works were also monitored with respect to gaseous emissions produced by the mixtures at the paver. In particular, by adopting a set of techniques and procedures developed and validated by the Politecnico di Torino in previous investigations, fumes were characterized in terms of their content of Volatile Organic Compounds (VOCs) and Polycyclic Aromatic Hydrocarbons (PAHs).

Finally, an assessment of the efficiency of compaction was performed by taking cores from the individual paving areas and by determining in the laboratory their volumetric properties (density, voids content and percent compaction).

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment):

- Workability properties are affected by the presence of rubber particles only in the case of coarse crumb rubber, with a significant reduction of self-compaction;
- Resistance to crack propagation, permanent deformation and master curve parameters are negatively affected by the presence of coarse rubber particles, whereas in the case of the use of ultrafine products an improvement was recorded especially in the case of base course mixtures;
- Gaseous emissions are not significantly affected by the presence of rubber particles.

From a quantitative point of view, by considering the final extension of paving works and the true composition (and compaction level) of laid mixtures, it can be concluded that Action 3.5 led to the recycling of approximately 480 tyres. Such a value corresponds to 27.8% of the quantity indicated in the project proposal (equal to 1,725 tyres). However, such a reduction is clearly justified by the decrease of the dosage of crumb rubber in the mixtures (target value reduced from 3% to 1%) which was established based on the experimental work performed during the mix design phase (Action 3.3.1).

Partial compensation of such a decrease came from the increased quantity of recycled tyres included in the expanded field activities of Action 3.4 (approximately 120 instead of 50). Furthermore, it should be pointed out that production and laying activities comprised with Action 3.5, including those of the reference mixtures (with no crumb rubber), corresponded to approximately 420 tonnes of bituminous mixtures. Such a quantity is 21.8% above the planned quantity indicated in the project proposal (equal to 345 tonnes).

From an economic viewpoint, the Beneficiary of the Action stated that the estimated cost of production and laying, in the hypothesis of more extended paving surfaces could be estimated in the order of 7.10 €/$m^2$.

Action 3.5 was successfully completed within the end of the TYREC4LIFE project.

The perspective for continuing the Action after the end of the project is encouraging. In particular, laboratory analyses will focus on the optimization of “dry” mixtures, with an emphasis placed on those containing coarser particles, which yielded less satisfactory results during the Action. Moreover, the actual performance of the laid mixtures will be monitored in time in order to assess their response under the effects of traffic and environmental factors.

It is envisioned that the “dry” technology may be attractive for Contractors and Administrations as a possible alternative to the “wet” one. Thus, other mix design and monitoring activities may be carried out in the future to further support the adoption of such a technology.

**Action 3.6. Trial reduced-scale experimental sections with "wet" technology**

Beneficiary responsible for implementation of the Action:

Brillada Vittorio & C.
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | × | × | × | × | × | × | × | × | × | | | | | | | |
| 1st Amendment | | | × | × | × | × | × | × | × | × | × | | | | | | | |
| 2nd Amendment | | | × | × | × | × | × | × | × | × | × | | | | | | | |
| Effective | | | | | | | | • | • | • | • | • | • | • | • | • | • | |

Description:

In the TYREC4LIFE project proposal originally approved by the European Commission, Action 3.6 was included as a preparatory activity to full-scale implementation, foreseen in Actions 4.1 and 4.2. In particular, following the laboratory work on various types of bituminous mixtures (Action 3.2), reduced-scale sections were planned in order to fine-tune formulations and laying conditions (i.e. temperature and rolling patterns).

Total extension of the trial pavements was fixed at 5,000 $m^2$, with a design thickness of 3 cm. In the hypothesis of 8.5% (by weight of dry aggregates) asphalt rubber content of the laid mixtures and 18.5% crumb rubber content (by weight of total binder), this would lead to the recycling of approximately 850 tyres (erroneously indicated as 980 in the proposal).

Action 3.6 was postponed due to a change in the Beneficiary, caused by the fact that one of the partners (Co.Ge.Fa.) withdrew from the project and was replaced by Brillada Vittorio & C. Further delays were caused by unfavourable weather conditions and by the interference with other Actions in which the new Beneficiary was directly involved (Actions 3.3.1, 3.3.2, 3.4 and 3.5, related to the development and implementation of the "dry" technology).

As the project progressed, the satisfactory results achieved during laboratory investigations carried out in Action 3.2 suggested that the reduced-scale sections planned in Action 3.6 could be changed in terms of their technical value so to explore the effects caused by further variations of mixture type and composition. In particular, it was decided that paving operations would consider the placement of a gap-graded mixture containing reclaimed asphalt pavement (RAP) material, previously subjected to mix design studies as part of Action 3.2. For comparison purposes, it was established that paving trials would also include the laying of a reference gap-graded mixture (with no RAP, similar to the mixtures laid as part of Actions 4.1 and 4.2) and a dense-graded mixture (similar to the one laid as part of Action 4.2).

The site selected for trials was the parking lot of a shopping mall (Gross Iper), located in the territory of the city of Leinì (Torino). As shown in the Report provided in attachment (identified as one of the deliverables of the TYREC4LIFE project), the total paving surface covered by paving trials was equal to 9,600 $m^2$, with a target laying thickness of 3 cm. Based on the requests of the owner of the infrastructure, it was agreed that the individual mixtures would be placed in different areas as indicated in the following:

- The gap-graded mixtures containing RAP on the access road to the parking lot, on a total surface of approximately 2,000 $m^2$ (subjected to a higher volume of moving traffic);
- The reference gap-graded mixture on a limited portion, of approximately 1,800 $m^2$, of the parking lot;
- The dense-graded mixture on the rest of the parking lot, on a total area of approximately 5,800 $m^2$.

Production and construction activities were carried out by the Beneficiary of the Action (Brillada Vittorio & C.) on September 20$^{th}$, 2015. Monitoring activities and subsequent testing were performed by the Politecnico di Torino. No major problem was reported in any phase of the Action.

Bituminous mixtures were produced in the same plant, owned and operated by Sintexcal s.p.a., which provided those which were laid as part of Actions 4.1 and 4.2. The asphalt rubber binder was also similar to the one employed in these Actions since it was once again supplied by Asphalt Rubber Italia (the only Italian producer). Job mix formulae were defined on the basis of the information gathered in Action 3.2 and on supplementary information obtained from the production plant.

Laying of the bituminous mixtures occurred after the preliminary cleaning of the existing pavement surface, followed by the application of an emulsion tack coat. Laying was carried out by employing a standard paver, while compaction was thereafter performed by making use of a tandem vibrating roller (Dynapac CC232HF). Pictures of paving operations are shown in the Report provided in attachment.

During laying operations samples of the bituminous mixtures were taken from the paver and thereafter employed in the laboratory for the assessment of their composition and for the evaluation of their volumetric and mechanical properties (following Marshall or gyratory compaction). Results were compared to those obtained in the mix design studies (Action 3.2) and to those of the other asphalt rubber mixtures laid during Actions 4.1 and 4.2.

From a quantitative point of view, by considering the final extension of paving works and the true composition (and estimated compaction level) of laid mixtures, it can be concluded that Action 3.6 led to the recycling of approximately 1,400 tyres. Such a value corresponds to a 43.3% percent increase of the quantity indicated in the project proposal (equal to 980 tyres).

From an economic viewpoint, the Beneficiary of the Action stated that the estimated cost of production and laying, in the hypothesis of more extended paving surfaces could be estimated in the order of 9.59 €/$m^2$ for the gap-graded mixture and of 7.45 €/$m^2$ for the dense-graded mixture.

Action 3.6 was successfully completed within the end of the TYREC4LIFE project.

The perspective for continuing the Action after the end of the project is encouraging. In particular, laboratory analyses will continue for the evaluation of the structural properties of the laid mixtures, while field work will be integrated with the assessment of their performance under the effects of traffic and environmental factors.

It is envisioned that the solution of including RAP in the formulation of gap-graded mixtures containing asphalt rubber may be attractive for Contractors and Administrations due to its reduced production costs. Thus, other mix design and monitoring activities may be carried out in the future to further support the adoption of such a technology.

**ACTION 4: IMPLEMENTATION ON INFRASTRUCTURES**

## Action 4.1 Road construction – Provincia di Torino / Città Metropolitana di Torino

Beneficiary responsible for implementation of the Action:

Città Metropolitana di Torino
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | × | × | × | | | | | | | | | |
| 1st Amendment | | | | | | | × | × | × | × | × | × | | | | | | |
| 2nd Amendment | | | | | | | × | × | × | × | × | × | × | × | | | | |
| Effective | | | | | | | • | • | • | • | • | • | • | • | | | | |

Description:

Action 4.1 was conceived in order to provide the TYREC4LIFE project its required demonstrative character, with the laying of bituminous mixtures containing crumb rubber on selected infrastructures of the provincial road network. It was envisioned that selection of materials and mix design analyses would be carried out according to the results of previous investigation phases (Actions 2.4, 3.1 and 3.2) and that the sections subjected to paving operations would be identified coherently with the needs of the Administration of providing the public with safe, durable and reliable road pavements.

Total length of the trial sections was indicated (in the first amendment to the initial proposal) equal to 1.5 km, with the expected laying of a gap-graded mixture containing standard aggregates (on 1 km, 10 m width, 3 cm thickness, 8.5% asphalt rubber by weight of aggregates) and of a gap-graded mixture produced and laid at reduced temperatures (on 0.5 km, same width, thickness and asphalt rubber content). This would lead to the recycling of approximately 2,550 tyres (erroneously indicated as 2,733 in the amendment).

The activities in Action 4.1 of the Province of Torino started in 2012 with the approval of the workplan for the paving of two road sections using bituminous mixtures containing crumb rubber from end-of-life tyres (DGP, Decision of the Provincial Executive, n. 52280/2012 dated December 21st, 2012). However, delays occurred in the progress of the Action as a result of the budget cuts to which Italian Local Authorities were subjected (through the so-called "Stability Pact"). Thus, a first request for amendment was submitted to the European Commission on 05/06/2013, with the proposal of a new timetable in which paving works were planned in the second quarter of 2014.

After approval of the Province budget in June 2013, the design of paving works was finalized with the cooperation of the Politecnico di Torino.

As a result of the analysis of existing maintenance needs of the provincial network, and following preparatory surveys on candidate infrastructures, the following sections were selected for paving:

- Section on the S.P. 503 (Baio Dora), a new infrastructure not yet open to traffic, on which laying of the gap-graded mixture containing standard aggregates was scheduled;

- Section on the S.P. 53 (San Giorgio - Caluso), an existing infrastructure (in average distress conditions), on which planned paving works would consist in on overlay performed by employing the gap-graded mixture produced and laid at reduced temperatures.

Technical Specification were prepared by the Politecnico di Torino and were included in the definitive-executive design, approved in December 2013 (DGP n. 46413/2013 dated December 31st, 2013).

Construction costs were computed by the beneficiary of the Action who for such a purpose referred to items of the standard unit price list of the Piedmont Region and to information gathered from suppliers. Consequently, reference unit prices (per square meter) for construction activities indicted in design documents were equal to 10.07 € for the gap-graded mixture and to 8.45 € for the dense-graded mixture.

The bid process was launched in April 2014 and works were subsequently awarded to the selected Contractor (Sintexcal SpA) by means of the Official Decree n. 14635/2014 dated July 14th, 2014.

Prices offered by the Contractor were 7% lower than those reported in the bidding documents, with a final unit values of 5.34 € for the gap-graded mixture and of 7.01 € for the dense-graded mixture.

The process outlined above, led to the need for a second request for amendment, issued on 29/09/2014, in which a further extension of the Action to the third quarter of 2014 was included in order to complete paving operations.

Field activities started in early September 2014 with the construction of reduced-scale pavement trial sections within the premises of the Sintexcal plant. As shown in the Report provided in attachment (identified as one of the deliverables of the TYREC4LIFE project), the total surface covered by paving trials was equal to:

- 210 $m^2$ (60 m length, 3.5 m width) for the gap-graded mixture containing standard aggregates (laid on September 5th, 2014);
- 210 $m^2$ (same length and width) for the gap-graded mixture produced and laid at reduced temperatures (laid on September 9th, 2014).

Target composition of the mixtures was defined by the Politecnico di Torino based on preparatory laboratory tests and in accordance with the previously-defined Technical Specifications.

Monitoring activities and subsequent testing were performed by the Politecnico di Torino. Obtained results indicated that while the first mixture could be considered approved and ready for full-scale laying, the second one, produced by employing an asphalt rubber binder modified in its composition by means of a viscosity-reduction wax, yielded unsatisfactory results.

Consequently, it was decided that further studies were needed in order to refine the formulation of gap-graded mixtures containing viscosity-reduction additives and that the paving solution adopted for the second section (S.P. 53) would entail the use of a dense-graded mixture.

A third pavement trial section, covering a surface of 210 $m^2$, was therefore constructed on September 25th, 2014. Corresponding analyses performed by the Politecnico di Torino led to the approval of the material and to its adoption for the planned paving works.

Paving works on the S.P. 503 were performed on September 25th, 2014, on a total surface of approximately 8,900 $m^2$ (1,200 m length, 9.5 m width) with a target thickness of the gap-graded wearing course equal to 3 cm.

Paving works on the S.P. 53 were performed on October 2nd, 2014, on a total surface of approximately 9,400 $m^2$ (1,050 m length, 9.0 m width) with a target thickness of the dense-graded wearing course equal to 3 cm.

During paving operations mixture temperatures were constantly monitored and samples were taken from the paver for subsequent determination of their composition, volumetrics (following Marshall of gyratory compaction) and mechanical properties. Paving works were also monitored with respect to gaseous emissions at the paver, which were characterized in terms of their content of Volatile Organic Compounds (VOCs) and Polycyclic Aromatic Hydrocarbons (PAHs). Finally, an assessment of the efficiency of compaction was performed by taking cores from the finished pavements and by determining in the laboratory their volumetric properties (density, voids content and percent compaction).

Monitoring activities and subsequent testing were performed by the Città Metropolitana di Torino (Roads Service Laboratory) and by the Politecnico di Torino (Road Materials Laboratory).

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment):

- A satisfactory agreement was found between target and actual composition, with a slight binder overdosage recorded for all mixtures;
- Thicknesses of laid courses was comparable to target, with the consequent possibility of verifying effectively employed quantities;
- Produced and laid mixtures showed acceptable volumetric and mechanical properties.

From a quantitative point of view, by considering the final extension of paving works and the true composition (and compaction level) of laid mixtures, it can be concluded that Action 4.1 led to the recycling of approximately 2,780 tyres. Such a value is very close to the quantity indicated in the project proposal.

Action 4.1 was successfully completed within the planned timeframe.

**Action 4.2: Road construction – Patrimonio Città di Settimo Torinese**

Beneficiary responsible for implementation of the Action:

Patrimonio Città di Settimo Torinese
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | × | × | × | | | | | | | | | |
| 1st Amendment | | | | | | | × | × | × | × | | | | | | | | |
| 2nd Amendment | | | | | | | × | × | × | × | × | × | × | × | × | | | |
| Effective | | | | | | | • | • | • | • | • | • | • | • | • | • | • | |

Description:

Action 4.2 was conceived in order to provide the TYREC4LIFE project its required demonstrative character, with the laying of bituminous mixtures containing crumb rubber on selected infrastructures in the network of the City of Settimo Torinese (TO). It was envisioned that selection of materials and mix design analyses would be carried out according to the results of previous investigation phases (Actions 2.4, 3.1 and 3.2) and that the sections subjected to paving operations would be identified coherently with the needs of the Administration of providing the public with safe, durable and reliable road pavements.

Total length of the trial sections in the initial project proposal was was indicated equal to 2 km, with the expected laying of an open-graded/controlled texture mixture (on 1 km, 10 m width, 3 cm thickness, 8.5% asphalt rubber by weight of aggregates) and of a gap-graded mixture containing lower-quality/recycled aggregates (on 1 km, same width, thickness and asphalt rubber content). This would lead to the recycling of approximately 4,540 tyres (erroneously indicated as 7,710 in the proposal).

The activities in Action 4.2 of Patrimonio Città di Settimo Torinese started in 2013 with the identification of candidate road sections. However, delays occurred in the progress of the Action as a result of the budget cuts to which Italian Local Authorities were subjected (through the so-called “Stability Pact”). Thus, two requests for amendment were submitted to the European Commission (on 05/06/2013 and 29/09/2014), with the proposal of new timetables in which paving works were finally planned in the first quarter of 2015.

The design of paving works was finalized with the cooperation of the Politecnico di Torino. Initial paving options were revised by taking into account the results obtained in full-scale construction operations performed in Action 4.1 and by considering specific needs of the local Administration. In particular, since in the Municipality of Settimo Torinese maintenance works are usually carried out by simply overlaying existing pavements with standard wearing course mixtures, it was decided to test similar solutions with innovative mixtures which in the future may be adopted to guarantee a longer life-time to pavement surfaces. The infrastructure which was selected for paving works was via Brescia, an arteria of strategic importance in the surroundings of the City of Settimo Torinese.

Preparatory surveys were performed in order to assess the state of surface distress of the existing pavement (visual analysis), its cross-section (by means of coring) and its cross-slope (by means of topographical measurements).

Gathered information led to the identification of specific points of the pavement for which it was deemed necessary to perform local repair works (consisting in pavement removal, compaction of the subgrade and reinstatement with standard bituminous mixtures) before laying of the new wearing courses. The road section was then divided into the three following sub-sections

- Sub-section I (length 590 m), on which it was scheduled to lay a dense-graded bituminous mixture containing asphalt rubber (similar to the one adopted for paving works on the S.P. 53 in Action 4.1) on top of a stress-absorbing membrane interlayer prepared by employing the same binder;
- Sub-section II (length 565 m), on which it was scheduled to lay a gap-graded bituminous mixture containing asphalt rubber (similar to the one adopted for paving works on the S.P. 503 in Action 4.1);
- Sub-section III (length 525 m), on which it was scheduled to lay a standard dense-graded bituminous mixture, of the same type normally adopted for maintenance operations.

Technical Specification were prepared by the Politecnico di Torino and were included in the definitive-executive design, approved in April 2015.

Construction costs were computed by the beneficiary of the Action who for such a purpose referred to items of the standard unit price list of the Piedmont Region and to information gathered from suppliers. Consequently, reference unit prices (per square meter) for construction activities indicted in design documents were equal to 9.10 € for the gap-graded mixture and to 7.66 € for the dense-graded mixture.

The bid process was thereafter launched (May 2015) and works were subsequently awarded to the selected Contractor (Sintexcal SpA) on June 16$^{th}$, 2015.

Prices offered by the Contractor were 5.878% lower than those reported in the bidding documents, with a final unit values of 8.57 € for the gap-graded mixture and of 7.21 € for the dense-graded mixture.

Field activities started on July 16$^{th}$, 2015 with the local repair works, while the laying of the wearing course bituminous mixtures in the three sub-sections occurred between July 27$^{th}$ and July 30$^{th}$, 2015. As shown in the Report provided in attachment, identified as one of the deliverables of the TYREC4LIFE project, the total surface covered by paving trials was equal to:

- 7,375 m$^2$ (590 m length, 12.5 m average width) for sub-section I;
- 7,062 m$^2$ (565 m length, 12.5 m average width) for sub-section II;
- 6,562 m$^2$ (525 m length, 12.5 m average width) for sub-section III.

Target composition of the mixtures was defined by the Politecnico di Torino based on the results achieved in Action 4.1 and in accordance with the previously-defined Technical Specifications.

Monitoring activities and subsequent testing were performed by the Politecnico di Torino. During paving operations mixture temperatures were constantly monitored and samples were taken from the paver for subsequent determination of their composition, volumetrics (following Marshall of gyratory compaction) and mechanical properties. Paving works were also monitored with respect to gaseous emissions at the paver, which were

characterized in terms of their content of Volatile Organic Compounds (VOCs) and Polycyclic Aromatic Hydrocarbons (PAHs). Finally, an assessment of the efficiency of compaction was performed by taking cores from the finished pavements and by determining in the laboratory their volumetric properties (density, voids content and percent compaction).

Monitoring activities and subsequent testing were performed by the Politecnico di Torino (Road Materials Laboratory).

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment):

- A satisfactory agreement was found between target and actual composition, with a slight binder overdosage recorded for all mixtures;
- Thicknesses of laid courses was comparable to target, with the consequent possibility of verifying effectively employed quantities;
- Produced and laid mixtures showed acceptable volumetric and mechanical properties.

From a quantitative point of view, by considering the final extension of paving works and the true composition (and compaction level) of laid mixtures, it can be concluded that Action 4.2 led to the recycling of approximately 2,250 tyres.

Action 4.2 was successfully completed within the end of the TYREC4LIFE project.

**Action 4.3: Road pavement monitoring – Skid resistance and roughness**

Beneficiary responsible for implementation of the Action:

Città Metropolitana di Torino
(Action developed with the cooperation of the Politecnico di Torino)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | | × | × | × | | | | | | | | |
| 1st Amendment | | | | | | | | × | × | × | × | × | × | | | | | |
| 2nd Amendment | | | | | | | | × | × | × | × | × | × | × | × | × | × | |
| Effective | | | | | | | | • | • | • | • | • | • | • | • | • | • | |

Description:

The goal of Action 4.3 was to provide an initial assessment of the functional performance of the innovative solutions adopted for the construction of the full-scale pavement sections (Actions 4.1 and 4.2). In particular, it was anticipated that monitoring would be carried out for a limited time period (6 months) by focusing on the two main factors which affect safety: skid resistance and roughness.

Techniques adopted for the assessment of the above mentioned characteristics were chosen among those which are available in most control laboratories and do not require the use of expensive equipment. In particular, measurements were carried out by referring to the following standards:

- Standard EN 13036-4 for the evaluation of the Skid Number (SN) by making use of the so-called British Pendulum (also known as “skid tester”);
- Standard EN 13036-1 for the evaluation of mean texture depth (MTD) by making use of the so-called sand-patch method;
- Standard EN 13036-7 for the evaluation of surface evenness, by making use of rigid bar (3 meters in length).

Investigations were performed by the mobile unit of the Roads Service Laboratory of the Città Metropolitana di Torino. No major problem was reported in any phase of the Action.

In synthesis the following conclusions were drawn (for details, see the Report provided in attachment, included as an additional deliverable of the TYREC4LIFE project):

- The dense-graded wearing course mixture exhibited a higher SN value than the gap-graded mixture (63 vs 59);
- The gap-graded wearing course mixture exhibited a higher MTD value than the dense-graded mixture (1.06 vs 0.64);
- For both types of wearing courses, the combination of SN and MTD values were extremely satisfactory, with a positive assessment of their safety potential;
- Both wearing course surfaces were found to be smooth with only minor deviation from ideal evenness.

Action 4.3 was successfully completed within the planned timeframe.

It is envisioned that in the future the innovative paving sections will be subjected to further monitoring.

**Action 4.4: Road pavement monitoring – Technical and environmental parameters**

Beneficiary responsible for implementation of the Action:

Politecnico di Torino
(Action developed with the cooperation of the Città Metropolitana di Torino and with Patrimonio Città di Settimo Torinese)

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | | | × | × | × | | | | | | | | |
| 1st Amendment | | | | | | | | × | × | × | × | × | × | | | | | |
| 2nd Amendment | | | | | | | | × | × | × | × | × | × | × | × | × | × | |
| Effective | | | | | | | | • | • | • | • | • | • | • | • | • | • | |

Description:

The goal of Action 4.4 was to provide an initial assessment of the structural performance and of the environmental compatibility of the innovative solutions adopted for the construction of the full-scale pavement sections (Actions 4.1 and 4.2). In particular, it was anticipated that structural monitoring would be carried out for a limited time period (6 months), while environmental parameters would be evaluated by mainly considering gaseous emissions produced during laying operations.

Although in the initial proposal it was indicated that the so-called technical parameters would be obtained from non-destructive tests carried out on site, a different choice was made as the project progressed. This was due to the fact that the adopted paving solutions consisted in the production and laying of wearing courses which due to their limited thickness contribute only marginally to the overall structural performance of pavements. Thus, their structural potential was highlighted by means of advanced performance-based tests which consider:

- stress-strain response under loading (by means of repeated compression tests carried out in triaxial conditions in the Asphalt Mixture Performance Tester, AMPT);
- resistance to crack propagation (by beans of semi-circular bending tests, SCB);
- resistance to accumulation of permanent strains (by means of Flow Number tests, FN).

Results of laboratory tests were supplemented by field monitoring activities which were carried out by means of periodic field surveys. In particular, pavements were inspected for the detection of the possible occurrence of surface distresses such as rutting, cracking and ravelling.

With respect to environmental compatibility, gaseous emissions at the paver, which were characterized in terms of their content of Volatile Organic Compounds (VOCs) and Polycyclic Aromatic Hydrocarbons (PAHs). Techniques for sampling and analysis were those developed by the Politecnico di Torino in previous research projects, with the parallel evaluation of fumes at the paver's driving seat (position D) and at the screed (position S). Wind speed and laying temperature were also recorded since they may significantly affect the release and migration of fumes.

Investigations were performed in the Road Materials Laboratory and in the Environmental Chemistry Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

In synthesis the following conclusions were drawn (for details, see the Report provided in attachment, included as an additional deliverable of the TYREC4LIFE project):

- Structural properties of bituminous mixtures containing asphalt rubber are totally satisfactory with respect to future required field performance;
- Gaseous emissions are affected by laying temperature and by binder content, but the presence of rubber does not seem to cause major effects on the concentrations of VOCs and PAHs.

Action 4.4 was successfully completed within the planned timeframe.

It is envisioned that in the future the innovative paving sections will be subjected to further monitoring.

**Action 5: Life cycle risk assessment**

Beneficiary responsible for implementation of the Action:

Politecnico di Torino

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | | | | × | × | × | × | × | | | | | | | | |
| 1st Amendment | | | | | | × | × | × | × | × | × | × | × | × | | | | |
| 2nd Amendment | | | | | | × | × | × | × | × | × | × | × | × | × | × | × | |
| Effective | | | | | | • | • | • | • | • | • | • | • | • | • | • | • | |

Description:

Action 5 was entirely dedicated to the evaluation of the considered paving technologies in terms of their effective environmental impact and of the effects which they may have on the health of working crews. For such a purpose, an innovative procedure was developed which combines Life Cycle Assessment (LCA) tools with sanitary-environmental Risk Analysis (RA) models. The ultimate goal of the activity was to highlight in differential terms the effects caused by the inclusion of crumb rubber in bituminous mixtures.

LCA and RA procedures were initially applied to the two full-scale trial sections, successfully completed on two extra-urban roads as part of Action 4.1. Analyses were thereafter extended to the reduced-scale pavement sections constructed as part of Actions 3.4 and 3.5 by employing “dry” mixtures produced by means of the prototype device developed during Actions 3.3.1 and 3.3.2.

In the case of the road sections built as part of Action 4.1 LCA was carried out by considering construction and future maintenance scenarios of the two innovative wearing courses which were compared to those of a standard bituminous mixture. In the case of the “dry” mixtures, LCA was carried out following the process cradle-to-gate; in fact, the system boundaries comprised only the raw and processed materials and the construction phase. The use phase, maintenance and end-of-life were not taken into account.

RA activities were based on the results yielded by laboratory analyses performed on the gaseous emission sampled during construction operations. Moreover, In order to expand LCA analysis and to include RA as subset to LCA, ILCD recommendations were considered in the analysis of environmental sustainability of the full-scale trial sections.

Investigations were performed by the Beneficiary of the Action (Politecnico di Torino). No major problem was encountered in any phase of the Action.

In synthesis, the following conclusions were drawn (for details, see the Report provided in attachment, identified as one of the Deliverables of the TYREC4LIFE project):

- Results obtained for the different wearing courses, expressed in terms of selected environmental indicators, showed that use of rubberized binders produced by means of the wet technology leads to significant benefits with respect to standard paving solutions (reduction of 48-51% energy consumption and 41-50% greenhouse gas emissions);
- In the case of the “dry” technology, incorporation of crumb rubber from end-of-life tyres in the base and wearing course mixtures does not necessarily produce the

same benefits than in case of “wet” technology. In fact, for the case studies considered, the eco-profile of the corresponding pavements was found to be approximately equivalent to that of a standard cross section.

Action 5 was successfully completed within the planned timeframe.

# 5. Dissemination actions

## 5.1. Objectives

The objective of the dissemination activities performed was to make target groups aware of the technological solutions developed throughout the project lifespan. Such solutions, in turn, have the goal to increase the use of scrap tire rubber in road pavement in Italy.

The main target group is made by local administrators (in particular, but not exclusively, belonging to municipalities), given the fact that they are in charge of the management of the Italian road system.

The overarching goal is achieved through sub-objectives summarized below which also target specific stakeholders, beneficiaries or interested actors:

- Validation of the use of open graded and controlled texture bituminous mixtures: this objective includes the delivery of results that are of scientific relevance and constitute the starting point for the economic exploitation of the outputs achieved. The dissemination in this case is directed towards researchers, analysts, environmental experts
- Evaluation of the potential use of reduced-quality or recycled aggregates. Also in this case the assessment reaches mainly environmental specialists, researchers and scholars, but is additionally targeted to administrators and citizens
- Development of solutions for the reduction of energy consumption and emissions; dissemination here regards businesses, researchers, public authorities in charge of environmental issues
- Implementation of the “dry” technology. The target actors and stakeholders mentioned above can also include Business support centers, investors (or “business angels”), market actors, local authorities, public administrators.

## 5.2. Dissemination actions

**Action 6.1 Project website**

Beneficiary responsible for implementation of the Action:

Città Metropolitana di Torino

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | × | × | × | × | × | × | × | × | × | × | × | × | | | | | |
| 1st Amendment | | × | × | × | × | × | × | × | × | × | × | × | × | × | | | | |
| 2nd Amendment | | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | |
| Effective | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |

Description:

The Coordinating Beneficiary has developed a section of its institutional web site dedicated to the project - http://bit.ly/1LejVk7 (on the internet site www.provincia.torino.gov.it) e http://bit.ly/1O1pXVh (on the internet site www.cittametropolitana.torino.it)

This section is on-line from December 2011, as scheduled, and it is located under the thematic section dedicated to environment.

This section has been used as a visibility and dissemination tool during the first months of project implementation, notably for the organisation of the kick-off meeting that took place on 13th December 2011. In this section, it is possible to find out information about the project activities, to know the project partners and to download project brochures, posters and technical presentations.

Moreover, to give more visibility to Tyrec4life, the Coordinating Beneficiary decided to open a new web domain: **www.tyrec4life.eu.** From now on, all project activities will be disseminated throughout the dedicated website.

Finally CRF has published a page dedicated to Tyrec4life in the FIAT Group website specialized for management of ELVs, that has the aim to encourage the matchmaking between demolition companies and recycling companies: **www.carecycling.fiat.com.** The project has also been cited in the 2014 FCA Sustainable Report, which is an international document summarizing the main activities and results concerning the Group's sustainability and is publicly available at the website: **http://2014sustainabilityreport.fcagroup.com.**

The TyRec4Life project was also cited as an example of best practice inside the ELT Committee (established by the Ministerial Decree n. 82/2011) activity report, which was published during an event with the presence of the Italian Environment Ministry, Gian Luca Galletti.

The structure of the website has been modified and updated including the results achieved in time, the information sheets and the deliverables of the actions as long as these are completed.

Special attention was paid to the section “Eventi e news” (“News and Events”) containing both information directly related to the project and general information on the issue of ELT sand their recycling.

To ease the consultation, the news have been listed in chronological order (by year / month).

The list of news published from Jenuary 2015 can be found at http://bit.ly/20mbL08 and the list of news published from September 2011 to December 2014 can be found at http://bit.ly/1Xg7P0Q

Following the name change from the Province of Turin to the Metropolitan City of Turin and the consequent creation of the new web portal www.cittametropolitana.torino.it, even the pages dedicated to the project have found their place on the new portal. In any case, the pages dedicated to the project can also be found directly at www.tyrec4life.eu.

The aim of the website, in addition to giving maximum visibility to the activities and progress of the project, is to provide visibility to news regarding the biggest issue in the handling of scrap tires. To this end, in the “Events and News” section, further news are published until the end of December 2015.

From the end of 2011 to the end of January 2016, the website was accessed over 4,800 times (Unique page-views using Google Analytics). The website analysis shows that the overwhelming majority of visitors comes from Italy and consults the pages in Italian. The pages in Italian are also consulted by visitors accessing the site from abroad.

The foreign countries from which the site was accessed, with the exception of Belgium as it is assumed that in the majority of cases the website was accessed by the project evaluation commission, are: Chile, Switzerland, the United Kingdom, Denmark, Spain, France, Tunisia, Greece, Israel, Romania, and the United States.

It should be noted that there was a peak in access from the United States during the “2013 study tour”.

**Action 6.4 Organisation of project conferences**

Beneficiary responsible for implementation of the Action:

Ceipiemonte

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | × | | | | | × | | | | | | × | | | | | |
| 1st Amendment | | × | | | | | × | | | | | | × | | | | | |
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| Effective | | • | | | | | • | | | | | | | | | | • | |

Description:

To date the partner Ceipiemonte has already organized two project conferences, namely

- first project conference connected with the kick-off meeting on 13 December 2011. Details in http://bit.ly/1Xg7P0Q - news of December 2011

- second project conference – seminar "Tyrec4life: innovative technology, environmentally sustainable road pavements", - Torino, 27 March 2013. Details in http://bit.ly/1Xg7P0Q - news of March 2013

The meeting was attended by FISE-UNITE, ECOPNEUS, project partners, and several other companies operating in the discarded tire dust and bitumen mixture production sectors, for a total of about 60 people.

The meeting was opened by the Road Practicability Assessor of the Province of Turin, followed by the contributions of FISE-UNITE, ECOPNEUS and the city of Settimo Torinese. They all stressed the importance of this project as an engine for a widespread development of bituminous conglomerates containing additives of discarded tire dusts and no longer relegated to just experimental interventions.

The other speakers explained in turn the technical content of the project by highlighting in particular the project elements of concreteness and developments in terms of technical innovation expected.

The meeting was concluded by the Minister for Environment of the Province of Turin, who drew the attention to the minimization aspects of the environmental impacts associated with the project (waste recycling and recovery). Photo gallery at http://bit.ly/1ooFolI

Approximately 60 people participated in the second conference, including two representatives of ETRMA-European Tyre & Rubber Manufacturers' Association.

Photo gallery at http://bit.ly/1nVzd7Y

This project conference was organized in conjunction with the visit to Turin of a delegation of technicians participating in an exchange between the Province of Turin and the public administrations of Brazil and Sub-Saharan Africa. Therefore, it was also an opportunity to disseminate objectives, methodologies, and initial results in an extra-European environment. The project raised such great interest, particularly among the Brazilian technicians, that during the final conference organized in Brasilia in April 2013, within the work of the “II Encontro dos Municìpios com o desenvolvimento sustentável”, in which the project coordinator Agata Fortunato also participated, a follow-up on Tyrec4life was explicitly requested (http://bit.ly/1Lemp25).

The final conference was held, consistent with the prolonging of the project, on September 18, 2015.

In order to maximize participation and best enhance both the technical presentation of the project and the presentation of the results to political decision makers (Action 6.5. Conferences for Decision Makers), in addition to a meeting with those working in the industry (Action 6.6. Crumb Rubber Manufacturers’ workshop), it was considered more efficient to organize an event combining these three elements. For this purpose, the event was subdivided into two parts: the first, involving the technical presentation of the results by the project partners; and the second, a round table discussion with the participation of a qualified panel of several people involved in the outcome of the project in various ways.

This final event took place in the prestigious grand hall of the Department of Architecture of the Polytechnic University of Turin hosted inside the 17$^{th}$-century Castello del Valentino. Over 100 people participated in the day’s events, including university professors, those working in the highway sector, builders, local public administrators, company representatives, citizens’ committee representatives, and environmental organizations.

The gathering, meant to illustrate the results obtained over four years of study and experimentation, was carried out in two distinct parts that were closely connected to one another. In the first part, technical-scientific reports were provided by the technicians who have been working on the project since its inception and have been following its evolution; and the second part consisted of a round table discussion bringing together all the stakeholders and industry players.

The choice was made to tackle and develop the entire *corpus* of the project in one single day, rather than splitting it up into three different gatherings, in order to render the event as efficient, coherent, and productive as possible. In fact, we are convinced that, in addition to making the results of the hard work carried out during this time public and available, it is essential to lay the foundations for a fruitful exchange of ideas and opinions by shedding light not only on the specific needs of the different people involved and on the development opportunities, but also, naturally, on the various kinds of obstacles and entities that those working on the project in various ways find themselves having to confront.

Therefore, during the first part of the conference, participated in by (in addition to the presence of local politicians) professors from the Polytechnic University of Turin, technicians from the Metropolitican City of Turin (formerly the Province of Turin), and the Heritage Society of Settimo Torinese, as well as representatives from the Fiat Research Center and Brillada Vittorio, the working methods and results of the technical-scientific work carried out both in the lab and directly on the field were illustrated for the this large audience. The audience was made up of researchers and technicians, from representatives from the production industry and tire recovery/recycling.

During the round table discussion that immediately ensued, there was an exchange among the different players involved in the scrap tire industry in various ways: from scrap tire collectors, to those who recover/transform these tires, to the final users, to representatives of local communities and research institutes, as well as, naturally, national politicians, who play and can play an essential role in outlining future strategies for the entire sector.

The discussion, which was extremely varied and a source of interesting food for thought, touched upon several features that distinguish such a unique industry as the scrap tire industry. In fact, the topics discussed ranged from regulatory and fiscal issues, technical-scientific issues, organizational and logistical problems linked to the collection and treatment of scrap tires, to the use of modified asphalt on our roads, on the fundamental role that politics, at the local level but mainly at the central level, plays in facilitating the spread of these new materials.

This occasion was, therefore, very fruitful not only because it succeeded in bringing together the various souls of the project to dialog, but also because it created the conditions to explore the potential and problems presented by the alternative use of scrap tires. The following is a summary of some of the interesting considerations that emerged during the discussion.

- Innovation and technology manage to create a better product, and LCA (Life Cycle Analysis) has shown that there are savings from an environmental and economic point of view as this waste would have to be disposed of and that it is, however, possible to recover materials and not only energy, such as combustible energy.

- It is important to find a way to transform best practices by bringing them out of the realm of prototypes and experimentation and turning them into industrial realities that are quantitatively relevant.
- Try to move the system by providing for, within the regulations of reference, specific incentives.
- Provide municipalities with thorough information on GPP and its products, create stimulus so that the most costly phase of production is bypassed using incentives that are able to create the necessary conditions for effective applicability.
- The use of scrap tire dust in bituminous mixtures must not be the only outlet for this material, but rather other uses must also be considered, for example on sports fields.
- This road pavement's greatest cost, compared to the use of traditional asphalt, can be amortized rather easily by considering its lower maintenance costs, maintenance that can be postponed and less frequent compared to traditional roads.
- It is essential to have outlets for the products deriving from the treatment of tires. The government should reduce VAT-tax on this and other materials from the so-called circular economy to make the material produced by Italian pulverizers more competitive. The regions should include this type of asphalt on their price lists; the trade associations that are part of the UNI (Italian Organization for Standardization) should qualitatively classify the different types of dust and granules; and, finally, the Ministry of the Environment should see that the famous ministerial decree "End to Waste" is issued, establishing the technical features that scrap tire waste, which goes into the plants and is ground, must have once it comes out so as not to be identified as waste.
- Asphalt modified with dust requires less ordinary maintenance; the life of the pavement is prolonged. Comfort is improved thanks to the product's elasticity, which also provides more ease of movement and pavement impermeability, with the subsequent lack of deterioration of the subsurface.
- Monitoring for abandonment is absolutely a long-standing problem, not only tire abandonment, but also a whole range of products that are considered more harmful.
- Some high-risk sites must be identified and protected, safeguarded, and monitored. Hence, the use of video cameras is essential in the areas that are considered strategic.
- Local policies are needed, experimentation is needed, but what we urgently need is a regulatory framework and policy system that shoulders the burden of making some immediate decisions.
- The industry, from local to national institutions, works when there is a network of best practices. When you truly have a shared experience, you probably do not have anything more to come up with, but rather you have things to bring up to standard and put into a network.
- The importance of education in the prevention of waste production.

All the technical presentation and the minutes of the round table discussion may be found on the website of the Metropolitan City of Turin at the following address:
http://bit.ly/21BQsNU

**Action 6.8.5. Benefit Assessment of Project's Profitability (BAPP)**

Beneficiary responsible for implementation of the Action:

Patrimonio Città di Settimo Torinese

Planning and progress of the Action:

| | 2011 | | 2012 | | | | 2013 | | | | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Proposal | | | × | × | × | × | × | × | × | × | × | × | × | | | | | |
| 1st Amendment | | | × | × | × | × | × | × | × | × | × | × | × | × | | | | |
| 2nd Amendment | | | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | |
| Effective | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |

Description:

To ensure a correct analysis of the possible benefits of using this new technologies of scrap tyres in bituminous mixtures for paving works, Patrimonio Città di Settimo Torinese started the collection of data on similar applications performed on behalf of the Municipality of Settimo in recent years.

Additionally, Patrimonio started a collaboration relationship with the Province of Torino in order to define the terms of reference for the expenditures to be carried out, and to check how the market may react to the technical requirements connected with the ongoing experimentation.

The BAPP contains three parts:

1. Description of the state of the art (present and past experiences in processes of road implementation). This section will be describing the conditions and quality of public service response to road implementation and maintenance. In detail, major road works carried out in the past ten years in the Municipality of Settimo Torinese have been taken into consideration
2. Proposal of indicators of public profitability (environmental, Economic and public health performances). This section will be providing the indicators, from ongoing and past experiences, useful to quantifying the profitability of each choice during the selection, implementation, monitoring and maintenance phases of the project. The indicators considered will be the economic elements and the aspects regarding the provision of public services for each alternative solutions.
3. Assessment of project profitability from a public perspective. This section will evaluate the project from a specific point of view. For Patrimonio Città di Settimo Torinese it is important to understand and be able to communicate the community perspective of technical choices.

The results of the above-described analysis have led to the conclusion that municipal administrations will only see the real benefit of using this technology when its cost is equal to that of the technologies currently being used and when it has been demonstrated that pavement made using this technology lasts no fewer than 15 years.

## 5.3 Analysis of long-term benefits

Long-term benefits of the TYREC4LIFE project are briefly discussed in the following.

Environmental benefits:

Within the LIFE+ program, the TYREC4LIFE project was centred in the field of "Environment Policy and Governance" and more specifically had a demonstration and innovation character related to the priority area of action n. 9 "Waste and Natural Resources".

Relevance from an environmental viewpoint of the topic addressed by the project can be appreciated by considering the growing need of maximizing the recycling of end-of-life tyres (ELTs) according to current European legislation. Moreover, past studies and experiences proved that crumb rubber derived by size-reduction from ELTs may be effectively used in paving applications as an additional component of bituminous mixtures.

Specific environmental benefits are associated to two of the objectives of the project, which were entirely reached:

- Objective n. 2: Evaluation of the potential use of reduced-quality or recycled aggregates;
- Objective n. 3: Development of solutions for the reduction of energy consumption and emissions.

Long-term benefits and sustainability:

A significant contribution to the success of the TYREC4LIFE project originated from Action 5, which was entirely dedicated to the evaluation of the considered innovative paving technologies in terms of their effective environmental impact and of the effects which they may have on the health of working crews.

For such a purpose, an innovative procedure was developed which combines Life Cycle Assessment (LCA) tools with sanitary-environmental Risk Analysis (RA) models. The ultimate goal of the activity was to highlight in differential terms the effects caused by the inclusion of crumb rubber in bituminous mixtures.

Another contribution of significant importance within the TYREC4LIFE project, which enhanced the interest it may generated in the various stakeholders involved in the road construction process, came from the analyses which were performed in assessing costs and potential long-term savings associated to the use of the considered innovative paving technologies.

In such a context, it should be mentioned that construction costs related to the works envisioned in Actions 3.5, 3.6, 4.1 and 4.2 were calculated based on the definitive-executive design phase based on items of the standard unit price list of the Piedmont Region, on information gathered from suppliers and on the additional contribution of the specialized Contractor involved as a partner in the project.

Nevertheless, the true economic impact of the analysed technologies will be assessed in the after-life phase of the project, in which it is envisioned that further paving activities will be initiated and completed.

Replicability, demonstration, transferability, cooperation:

Adopted paving solutions are fully replicable and were found to be compatible with the organization of involved Administrations. Cost-effectiveness may still be an area of further improvement.

The potential for commercial application of the "dry" technology, launched in the project by developing an innovative prototype, will be assessed in the first five years of the after-life of the project, in which the system will be available for demonstrative actions (and not for commercial purposes).

Market conditions will be developed by means of an adequate dissemination, with the overall goal of promoting the diffusion of technologies which require an initial greater investment but lead to a better life-cycle performance.

Best Practice lessons:

Best practices have been transferred into the Technical Guidelines issued during the project. It is envisioned that they will be fine-tuned as they will be adopted for other full-scale applications. Possible improvements may be sought in the performance-based testing of mixtures.

Innovation and demonstration value:

The innovative and demonstrative character of the TYREC4LIFE project is proven by its physical outputs, which will be further exploited in its after-life, are the following:

- A new full-scale prototype for the implementation of the "dry" technology, fully available for further experimental investigations;
- Approximately 42,000 $m^2$ of pavements with wearing courses containing asphalt rubber binders (thickness 3 cm) and 2,000 $m^2$ of two-layer pavements (total thickness 8 cm) constituted by bituminous mixtures produced by means of the abovementioned prototype device, all available for future monitoring under the effects of traffic loading and environmental factors.

Long term indicators of the project success:

Bibliographical references to the project, invitation to Conferences and Seminars, adoption of Technical Guidelines by Administrations, follow-up projects at the national and international level.

# 6. List of deliverables, publications and presentations of the project

**Deliverable:**

| | |
|---|---|
| **Action 2.1** | Evaluation of the current status of the recycling / energy recovery of End of-Life Tyres (ELTs) and End-of-Life Vehicles (ELVs) in order to achieve European targets |
| **Action 2.2** | Environmental evaluation of recycling technologies of crumb rubber from ELTs in comparison with solutions such as landfill disposal and energy recovery |
| **Action 2.3** | Environmental evaluation of the use of crumb rubber from ELTs in road paving technologies in comparison with standard solutions |
| **Action 2.4** | Evaluation of the current status of aggregates available for bituminous mixtures containing crumb rubber |
| **Action 2.5** | Evaluation of the current status of the crumb rubber availability in Italy |
| **Action 2**.6 | Screening for alternative material at short supply distance and |
| **Action 2**.6 | Geolocation of companies (GIS files) |
| **Action 3.1** | Characterization of asphalt rubber binders |
| **Action 3.2** | Characterization of bituminous mixtures containing crumb rubber from ELTs |
| **Action 3.2** | Technical specifications for the mix design and quality assurance of bituminous mixtures containing crumb rubber from ELTs |
| **Action 3.3.1, 3.3.2, 3.4 and 3.5** | Technical guidelines for the field implementation of the "dry" technology |
| **Action 3.6** | Technical guidelines for the field implementation of the "wet" Technology with the use of reclaimed asphalt pavement (RAP) |
| **Action 4.1** | Project delivery. Site monitoring report |
| **Action 4.**2 | Project delivery. Site monitoring report |
| **Action 4.3** | Road pavement monitoring: Skid resistance and roughness |
| **Action 4.4** | Road pavement monitoring: Technical and environmental parameters |
| **Action 5** | Life cycle risk assessment |
| **Action 6.8.5** | Benefit Assesment of Project Profitability BAPP |
| **Action 7** | After Life Communication Plan |

**Scientific publications:**


1. E. Santagata, D. Dalmazzo, M. Lanotte, M.C. Zanetti & B. Ruffino (2012). "Relationship between crumb rubber morphology and asphalt rubber viscosity", Proceedings, AR2012 5th Asphalt Rubber "Roads of the Future" International Conference, Munich, Germany, 23-26 October, 2012. pp. 513-532.
2. M.C. Zanetti, S. Fiore, B. Ruffino & E. Santagata (2013). "Use of crumb rubber in road paving applications: workers' health risk assessment", Proceedings, Fourteenth International Waste Management and Landfill Symposium, Santa Margherita di Pula, Italy, 30 September - 4 October, 2013.
3. M.C. Zanetti, S. Fiore, B. Ruffino, E. Santagata & M. Lanotte (2014). "Assessment of Gaseous Emissions Produced on Site by Bituminous Mixtures Containing Crumb Rubber", Construction and Building Materials, vol. 67, 2014, pp. 291-296.
4. M.C. Zanetti, S. Fiore, B. Ruffino, E. Santagata, M. Lanotte & D. Dalmazzo (2013). "Development of a laboratory test procedure for the evaluation of potential

gaseous emissions of asphalt rubber bituminous mixtures", submitted to the 3rd International Conference on Transportation Infrastructures - ICTI 2014, November 2013.

5. E. Santagata, M.C. Zanetti (2013). "Conclusioni e sviluppi futuri", in "L'impiego di prodotti da Pneumatici Fuori Uso nelle pavimentazioni stradali", Milano, Italia, 2013. pp. 111-113
6. M.C. Zanetti, S. Fiore, B. Ruffino, E. Santagata, D. Dalmazzo & M. Lanotte (2014). "Characterization of Crumb Rubber from End-of-Life Tyres for Paving Applications", Proceedings, SUM 2014, Second Symposium on Urban Mining, Bergamo, Italy, 19-21 May, 2014.
7. A. Farina, M.C. Zanetti, E. Santagata, G.A. Blengini & M.A. Lanotte (2014). "Life Cycle Assessment of Road Pavements Containing Crumb Rubber from End-of-Life Tires", Proceedings, International Symposium on Pavement LCA 2014, Davis, California, USA, 14-16 October, 2014.
8. E. Santagata, M. Lanotte, O. Baglieri, D. Dalmazzo & M.C. Zanetti (2014). "Analysis of bitumen – crumb rubber affinity for the formulation of rubberized dry mixtures", submitted to the American Journal of Applied Sciences.
9. M.C. Zanetti, B. Ruffino, E. Santagata, D. Dalmazzo & M. Lanotte (2014). "Determination of crumb rubber content of asphalt rubber binders", submitted to the American Journal of Applied Sciences.
10. E. Santagata, M.C. Zanetti , A. Fortunato (2015). "Il progetto europeo TYREC4LIFE", submitted to EDI-CEM Srl – Rivista "Strade & Autostrade"
11. E. Santagata, O. Baglieri, M. Alam, M. Lanotte & P.P. Riviera (2015). "Evaluation of rutting resistance of rubberized gap-graded asphalt mixtures", submitted to Bituminous Mixtures & Pavements VI – Nikolaides (Ed.)

**Presentations at conferences**

1. Turin - Italy, December 2011, kick off meeting
2. Rovereto – Italy, June 2012, "4° convegno nazionale asfalti gommati"
3. Munich - Germany, October 2012 "Asphalt Rubber 2012"
4. Turin - Italy, March 2013, Project Conference
5. Tashkent - Uzbekistan, April 2013, "TECHNICAL CONFERENCE State of art and future prospects in road and airport pavement engineering in Uzbekistan. Sharing the knowledge to go ahead
6. Rimini – Italy, November 2013, Ecomondo 2013: The importance of monitoring purchases: the APE project of the Province of Turin
7. Cagliari – Italy, September 2013, Sardinia Fourteenth International Waste Management and Landfill Symposium 2013: Use of crumb rubber in road paving applications: workers' health risk assessment
8. Las Vegas – USA, October 2013, "1st Annual International Recycled RUBBER Products (R2P) Technology Conference"
9. Turin – Italy, February 2014 Training course Valutazione dei possibili utilizzi nelle pavimentazioni stradali del polverino proveniente da pneumatici fuori uso
10. Brussels – Belgium, March 2014, IARC 2014: Development and implementation of innovative and sustainable technologies for the use of scrap tyre rubber in road pavements
11. Pisa – Italy, April 2014, ICTI 2014 - International Conference on Transportation Infrastructure: Development of a laboratory test procedure for the evaluation of potential gaseous emissions of asphalt rubber bituminous mixtures

12. Turin - Italy, October 2014. FLEX & THE CITY 2014. Products and Applications In Rubber Recycled For Roads, structures for use in urban planning and Transports - Seminar organized by ETRA / European Tyre Recycling Association: TYREC4LIFE: innovative technology, environmentally sustainable road pavements
13. Rimini – Italy, November 2014, Ecomondo 2014: Life Cycle Assessment (LCA) of road floorings containing powder of used tires (ELT)
14. Berlin – Germany, March 2015, IARC 2015: the roll-up of the TyRec4Life project has been exhibited during the International Automobile Recycling Congress, which was attended by around 300 stakeholders from different parts of the world
15. Brussels – Belgium, March 2015. ETRA 22th European Conference on tyre recycling. Innovative society: New opportunities for recycled materials
16. Turin – Italy, March 2015, "Advances in Quality Control and Quality Assurance in Road Constructions"
17. Turin - Italy, May 2015 Study visit of a Burmese delegation from PCCD-Pollution Control and Cleansing Department of YCDC-Yangon City Development Committee
18. Turin – Italy, May 2015, Study visit of a delegation from University of Maryland. The use of scrap tyre rubber in asphalt pavements Borgaro-Venaria ring road and TYREC4LIFE program
19. Dubai – EA, May 2015, "6th MIDDLE EAST BITUMEN/ASPHALT 2015"
20. Thessaloniki – Greece, June 2015, 6th International Conference "Bituminous Mixtures and Pavements"
21. Turin - Italy, September 2015, Final Connference
22. Venice - Italy, October 2015. FLEX & THE CITY 2015. Rubberised Asphalt and Recycled Tyre Applications for Roads and Urban Furniture
23. Rimini – Italy, November 2015, Ecomondo 2015, TYREC4LIFE: tecnologie innovative ed ecologicamente sostenibili per le pavimentazioni stradali
24. Rome – Italy, January 2016, "Conglomerati innovativi e ad elevate prestazioni. Un'opportunità per una lunga durata nel tempo"

Further presentations of the project are scheduled in the coming months.

**Layman's Report** is download at http://bit.ly/1QKtKhy

**Press releases and articles**
**List of Press releases – *Provincia di Torino* and *Città Metropolitana di Torino***
1. 2015 September 18
http://www.cittametropolitana.torino.it/cms/comunicati/ambiente/dopo-4-anni-di-sperimentazioni-tyrec4life-giunge-al-traguardo-l-utilita-del-polverino-da-pneumatici-esausti-per-asfaltare-le-strade
2. 2014 October 03
http://www.provincia.torino.gov.it/cgi-bin/ufstampa/comunicati/dettaglio_agenzia.cgi?id=9276
3. 2014 September 23
http://www.provincia.torino.gov.it/cgi-bin/ufstampa/comunicati/dettaglio_agenzia.cgi?id=9250
4. 2013 March 15
http://www.provincia.torino.gov.it/cgi-bin/ufstampa/comunicati/dettaglio_agenzia.cgi?id=8450

5. 2012 June 14
http://www.provincia.torino.gov.it/cgi-bin/ufstampa/comunicati/dettaglio_agenzia.cgi?id=7984

***Cronache da Palazzo Cisterna* – Provincia di Torino and Città Metropolitana di Torino**

1. 2015 September 11 – pg 6
http://www.cittametropolitana.torino.it/ufstampa/cronache/2015/dwd/num28.pdf

2. 2014 October 3 – pag 10
http://www.provincia.torino.gov.it/stampa/cronache/2014/num30.htm
3. 2014 September 12 – pag 12
http://www.provincia.torino.gov.it/stampa/cronache/2014/dwd/num27.pdf
4. 2012 October 12 – pag 4
http://www.provincia.torino.gov.it/stampa/cronache/2012/dwd/num26.pdf
5. 2012 January 20 – pag 9
http://www.provincia.torino.gov.it/stampa/cronache/2012/dwd/num1.pdf

***Italian Ministry of Environment***

1. 2015 September
http://www.minambiente.it/sites/default/files/archivio/allegati/life/life_tyrec_conferenza2015_programma_definitivo.pdf
2. 2014
http://www.pongas.minambiente.it/prodotti-e-materiali-home/finish/139-manuali-linee-guida/1107-il-capitale-di-esperienze-dei-progetti-life-ambiente-italiani-buone-pratiche-per-i-territori-delle-regioni-dell-obiettivo-convergenza
3. 2011 December 13
http://www.minambiente.it/sites/default/files/archivio/allegati/life/life_programma_incontro_tyrec4life.pdf

**List of Press article and newsletter**

1. 2016 February 15 - http://www.bostoncommons.net/waste-water-management-sustainable-development/?shared=email&msg=fail
2. 2016 February 01 - http://www.giornalistinellerba.it/2016/02/01/tyrec4life-gli-pneumatici-che-diventano-asfalto/
3. 2015 October 31 -https://5minutiperlambiente.wordpress.com/tag/progetto/
4. 2015 September 29 - http://rifiutizeroumbria.blogspot.it/2015/09/tyrec4life-il-progetto-per-una-corretta.html
5. 2015 September 23 - http://www.hydroaid-it.org/notizie/tyrec4life-le-opportunita-innovative-si-fanno-strada
6. 2015 September 23 - http://www.hydroaid.org/news
7. 2015 September 22 - http://www.rinnovabili.it/re-auto/torino-pneumatici-fuori-uso-333/
8. 2015 September 21 - http://www.ecodallecitta.it/notizie/383761/tyrec4life-il-progetto-per-una-corretta-gestione-degli-pneumatici-fuori-uso/
9. 2015 September 18 - http://www.comune.torino.it/ucstampa/2015/article_637.shtml
10. 2015 September 18 - http://www.torinoclick.it/?p=25698
11. 2015 September 18 - http://www.newspettacolo.com/news/view/163395-citta_di_torino_l_assessore_lavolta_sul_progetto_tyrec4life_news_torino_torino_piemonte
12. 2015 September 15 - http://www.casaeclima.com/ar_24132__Conferenza-finale-progetto-tyrec4life.html

13. 2015 September 14 - http://www.ansa.it/piemonte/notizie/europa/2015/09/14/ue-punta-su-riuso-pneumatici-progetto-tyrec4life-a-torino_73f70157-f66a-4f3d-a22a-bc17eea51396.html
14. 2015 September 8 - http://www.enzolavolta.it/wp/?p=4130
15. 2015 September - http://www.mater.polimi.it/mater/it/notizie-eventi/eventi-passati/2015/817-pneumatici-in-polvere-come-gli-pneumatici-esausti-diventano-pavimentazioni-innovative-conferenza-finale-del-progetto-europeo-tyrec4life
16. 2015 August 18 - http://lobiettivonline.it/torino-il-progetto-tyrec4life-in-dirittura-darrivo/
17. 2015 September 18 - http://www.noodls.com/view/B937EF3EC0A635A27ADDD35B376860326DFF4B2B?1531xxx1442588508
18. 2015 August 7 - http://247.libero.it/focus/33200261/89/riutilizzo-pneumatici-il-18-settembre-a-torino-conferenza-finale-del-progetto-tyrec4life/
19. 2015 August - http://iniziative.centroestero.org/iniziative.php?action=view&IDitem=1677
20. 2015 June 9 - http://online.stradeeautostrade.it/infrastrutture/pavimentazioni-e-manti/2015-06-09/il-progetto-europeo-tyrec4life-7513/
21. 2015 May - http://www.cittametropolitana.torino.it/europa/newsletter/news2015/maggio15.shtml
22. 2014 December 4 - http://www.egommerce.it/news/Con-Tyrec4life-l%E2%80%99asfalto-si-realizza-con-vecchi-pneumatici_353.html#Null
23. 2014 October 3 - http://www.obiettivonews.it/2014/10/03/san-giorgio-canavese-tyrec4life-lasfalto-rinnovabile/#.VC6-Mc4cRD8
24. 2014 October 3 - http://www.quotidianocanavese.it/made-in-canavese/san-giorgio-i-pneumatici-usati-diventano-asfalto-per-le-strade-del-canavese-2560
25. 2014 October 3 - http://lasentinella.gelocal.it/ivrea/cronaca/2014/10/03/news/posato-l-asfalto-del-futuro-sulla-strada-provinciale-53-1.10048734
26. 2014 October 2 - http://12alle12.it/borgofranco-divrea-sulle-strade-canavese-lasfalto-gomma-96603
27. 2014 October - http://www.lajsiab.com/WGl6bzdmRlpYR1Ex
28. 2014 September - http://www.provincia.torino.gov.it/europa/newsletter/News2014/settembre14.html
29. 2013 May 27 - http://www.rinnovabili.it/re-auto/asfalti-gommati-sicuri-silenziosi-e-green-828/
30. 2013 March 15 - http://ecodallecitta.it/notizie.php?id=374192
31. 2013 March – Api Flash (only paper copy, attached file)
32. 2012 May 31 - http://www.torinoscienza.it/articoli/e_sempre_su_strada_la_seconda_vita_degli_pneumatici_23415.html
33. 2012 January 12 - http://www.diggita.it/story.php?title=TyRec4life_a_Torino_ora_le_strade_si_fanno_con_i_pneumatici
34. 2012 January 12 - http://www.thinkinnovation.org/tyrec4life-a-torino-ora-le-strade-si-fanno-con-i-pneumatici/
35. 2012 January 10 - http://www.corriere.it/ambiente/12_gennaio_10/polverino-gomme-bitume-tagliacarne_f2a0e1c8-3b76-11e1-9a5f-c5745a18f471.shtml
36. 2012 January 10 – page non found now (see printing in ANNEX 07 - DISSEMINATION) Http://Www.Bioecogeo.Com/Bio/Ambiente
37. 2012 - http://www.comune.torino.it/pass/php/4/Salute.php?pag=53961
38. 2011 December 13 - http://www.ecodallecitta.it/notizie.php?id=109638

**Youtube footage**

1. February 2016, Giornalisti nell'erba
https://www.youtube.com/watch?v=QYVYErkdNrw
published on 02/01/2016, 70 views

2. October 2014 – action 3.3.2
https://www.youtube.com/watch?v=-MoCAmHWvkY
published on 11/18/2014, 234 views

3. September 2014 – action 4.1
https://www.youtube.com/watch?v=Xizo7fFZXGQ
published on 09/29/2014, 415 views

4. https://www.youtube.com/watch?v=-Aa0IXSaMGM
published on 09/10/2014, 634 views

5. May 2012, Università di Brescia
https://www.youtube.com/watch?v=f5u9d0Z5hYk
published on 05/25/2012, 31 views

6. December 2011 - Kick-off meeting
https://www.youtube.com/watch?v=MXwrlCVmGcg
published on 08/16/2012, 202 views