LAYMAN'S REPORT

POLYMIX

Polymer waste in asphalt mixes: a way to increase sustainability of road infrastructures

Content

Project data

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Project partners

University of Cantabria

(Project Coordinator)

ACCIONA Infraestructuras

AIMPLAS

(Plastics technology centre)

Consejería de Transportes e Infraestructuras de la Comunidad de Madrid

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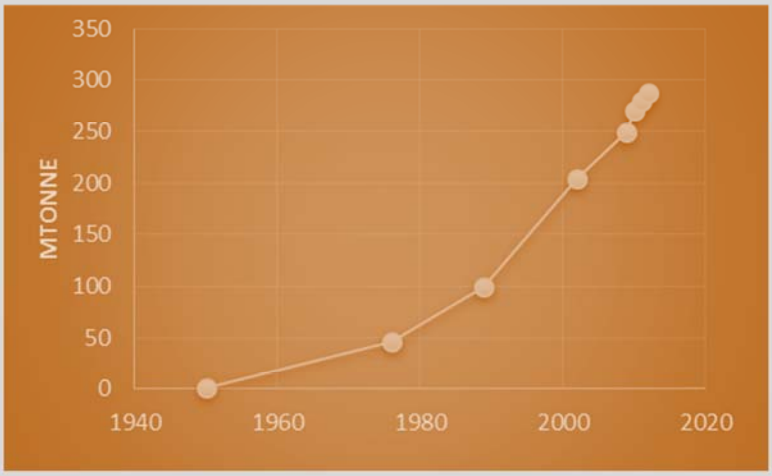
POLYMIX PROJECT

ENVIRONMENTAL PROBLEM

Consumption of polymeric products has increased dramatically over the past few decades. This trend results in the generation of a vast waste stream that needs to be properly managed in order to avoid environmental damage.

Nowadays, polymers are recycled at rates of only a few percent in most countries, so they are rapidly accumulating in unproductive and virtually permanent landfills. This waste disposal contributes significantly to their environmental impact. In addition, they take a long time to break down when landfilled, and each time there are more and more polymers products in the market being disposed of soon after their purchase. This kind of waste has a huge impact on the environment contaminating our soil and water. The possibility of using polymeric waste as raw material represents an alternative approach to a sustainable life cycle.

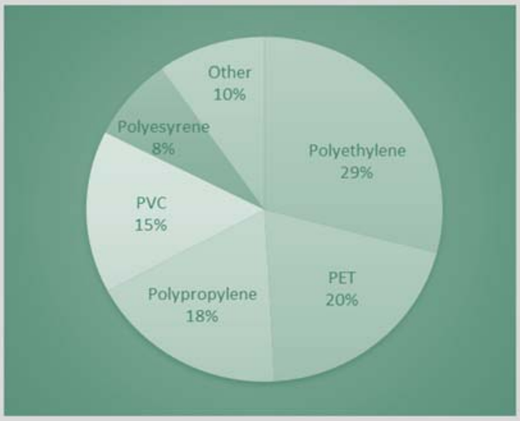
On the other hand, road transport infrastructure has a great impact on economy and society in Europe and globally. However, each road kilometre requires a large amount of materials (aggregates and bitumen) and energy not only in its construction but also in maintenance and rehabilitation. Hence, searching for most cost-effective and eco-friendly solutions will lead to a huge impact.



World Plastic Production (Source: PlasticsEurope)

PROJECT SOLUTION

In the POLYMIX project, the addition of polymer wastes to modify asphalt mixes was proposed. In this way environmental problems associated to polymer wastes would be reduced, permitting new alternatives for its reuse. These modified mixes were expected to present better physical and mechanical properties than conventional ones. Thus, reusing this type of waste by adding them into the asphalt mixes brings not only environmental advantages, but also increases the added value of the product.



Main plastics in market (PlasticsEurope, 2012)

Within the framework of POLYMIX project three of the most commonly used plastic polymers: polyethylene (PE), polystyrene (PS) and polypropylene (PP), as well as rubber from End-of Life tyres (ELT) were selected for modifying asphalt mixes.

Asphalt plant used in POLYMIX

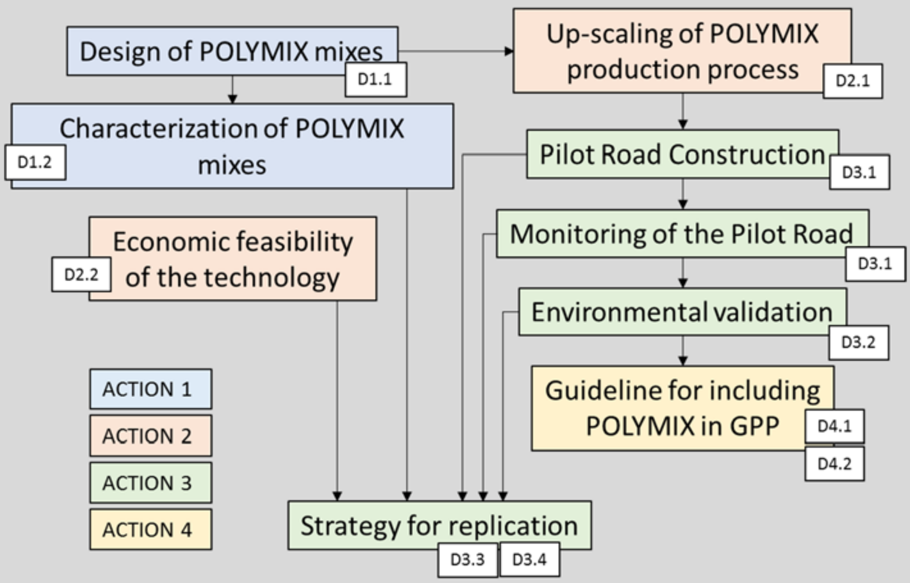
The use of polymers in bituminous mixes is not new. The modification of bitumen by incorporating polymers (wet process) is a common practice and high performance bitumen is obtained. However, specialized installations are needed and the process results complex and expensive.

The POLYMIX project proposes the modification of the asphalt mixes by adding the polymer directly to the mixer drum (dry process). This process is simpler, does not need significant initial investment and can be carried out in virtually any asphalt plant without modifications. The technology is, therefore, easily exportable allowing the polymer waste to be recovered where produced, reducing environmental and economic impacts.

WORK DESCRIPTION

The aim of the POLYMIX Project is the technical, economic and environmental demonstration of environmental friendly asphalt mixes using polymer waste for modifying mixes.

In order to achieve this objective, the work was divided into 6 Actions. The main activities carried out during the project and the relationship between tasks are shown in the following figure.



POLYMIX activities and structure

POLYMIX mixes design

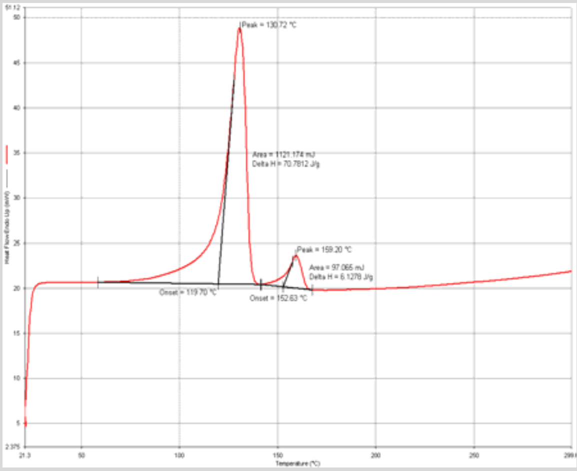
Standard or conventional hot mix asphalt (HMA) is defined as the combination of a hydrocarbon binder (bitumen) and mineral aggregates mixed together, so that all aggregate particles are coated by the binder.

POLYMIX project intended to reduce the environmental problems associated with polymeric waste by adding them into conventional asphalt mixes like any aggregate without modifying the binder, so the percentage of polymer waste added to the asphaltic mixture substitutes the same percentage of mineral aggregate.

Asphalt mixes (core samples from Pilot)

Selection of polymeric waste material streams

Firstly, the selection of the most suitable polymeric waste for the modification of asphalt mixes was carried out. For this application, the polymeric waste material to be used as modifier shall be as homogeneous as possible, both in composition and size grading, since it will be part of the aggregate structure of the resulting asphalt mixture. The minimum size grading is recommended in order to obtain a stable and homogeneous mixture, although the economic criterion has to be taken into account.



Differential Scanning Calorimetry,thermogram of Micronized PE drums

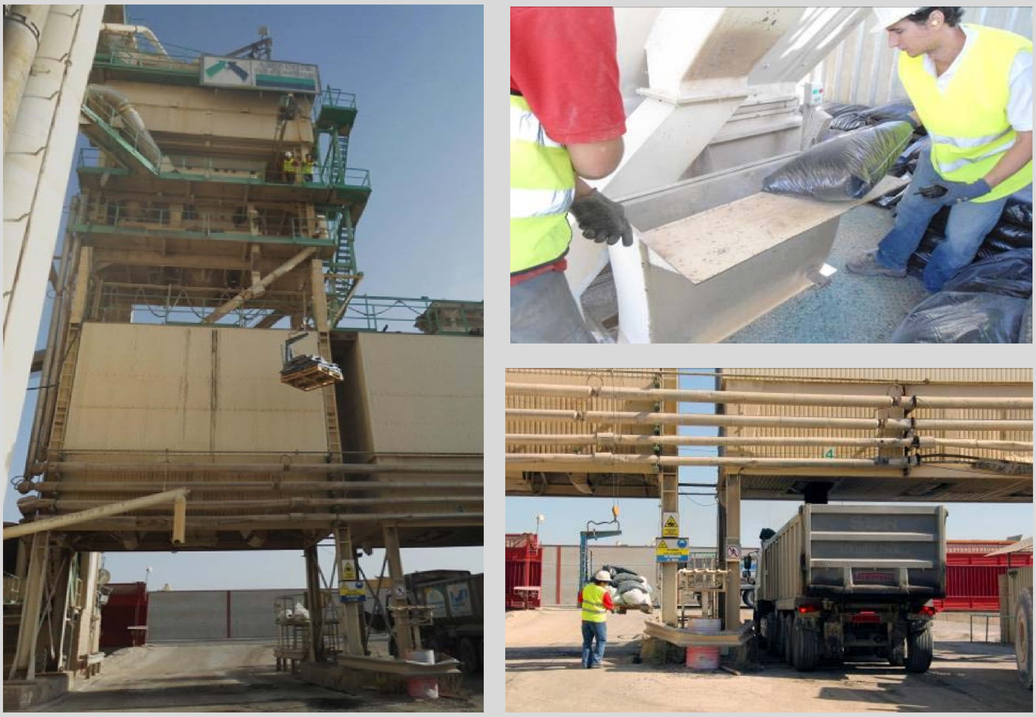
Moreover, it was necessary to previously characterize the polymeric material in order to discard potential performance risks due to the inclusion of this component, like the inappropriate thermal behaviour when facing the high temperatures during the mixture production. Thus, polymeric waste from different sources were characterized by thermal analysis.

POLYMIX mixes design and scaling-up

The polymers that fulfilled the requirements were added in different percentages to the asphalt mixture. These percentages of polymeric waste replace the same proportion of mineral aggregate in its smallest fraction: the filler. The final selection of the polymer waste stream and percentage of addition were carried out assessing the homogeneity, handling, workability and voids content of the produced mixes.

Wheel tracking test

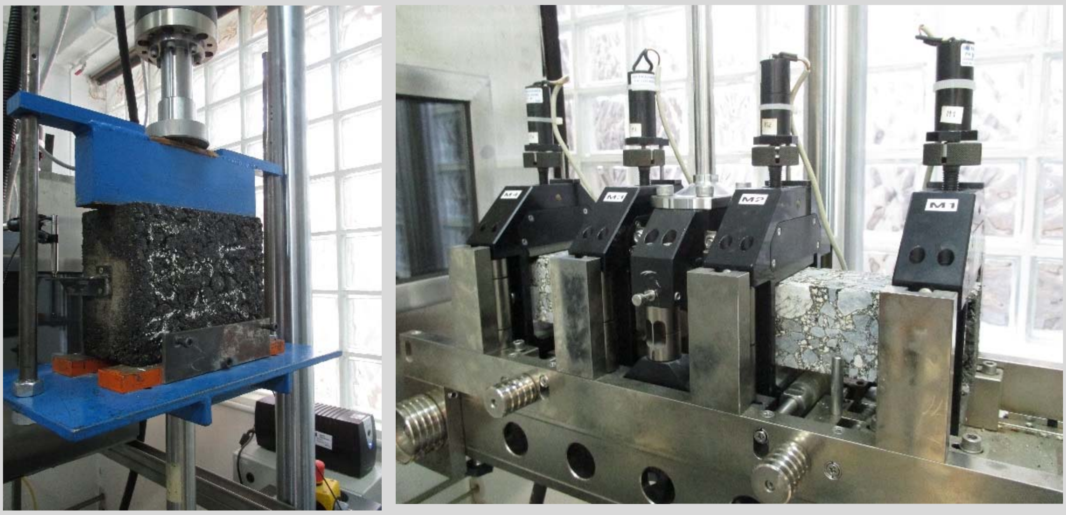
Since the asphalt mixes modified with recycled polymers are new and innovative products, previous to the implementation stage it was necessary to analyse the processes and equipment used in regular asphalt mixes production, and evaluate what changes or modifications were needed for the manufacture of the new mixes. The defined production process was successfully validated by testing a small batch of each type of polymer modified mixture produced at the asphalt plant.



POLYMIX production scaling-up

POLYMIX mixes characterization

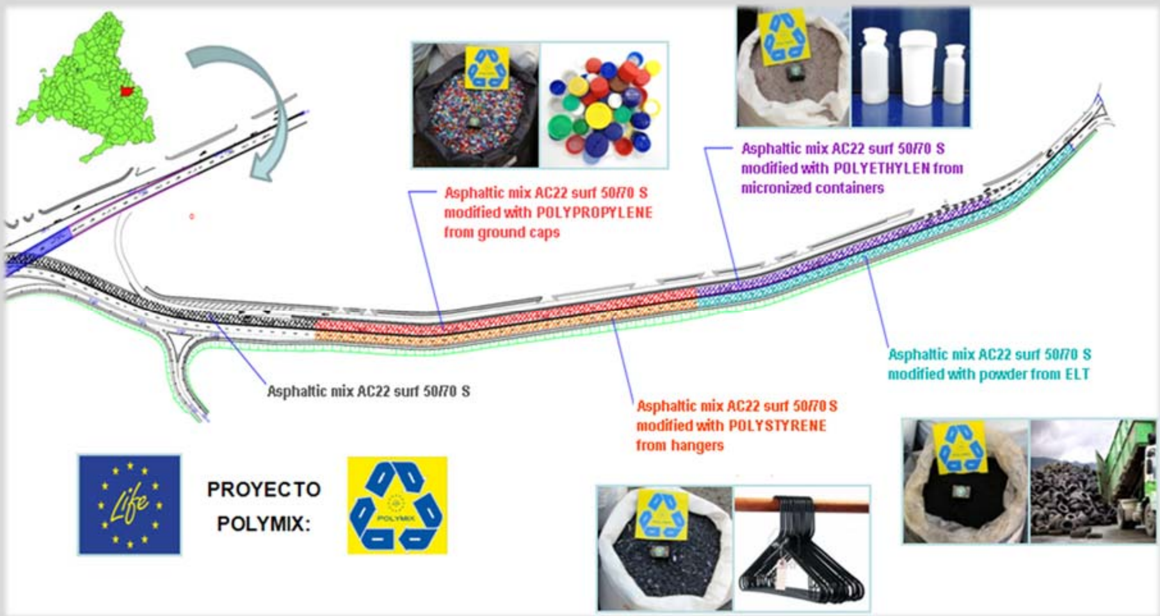
The mixes previously designed were characterized at the laboratory in order to accurately analyse the influence of the recycled polymer additive type in the asphalt mixture. Stiffness and dynamic modulus, fatigue resistance, skid resistance and the static adherence between layers were evaluated.



Roads laboratory

Technical validation

In order to demonstrate the technical feasibility of the technology, the four mixes designed and characterized at the laboratory were implemented at a real scale road and their performance assessed during 18 months. The road sections were built in a real highway in Madrid (Spain), between Arganda del Rey and Alcalá de Henares (M-300).



Trial section road in M300 Madrid

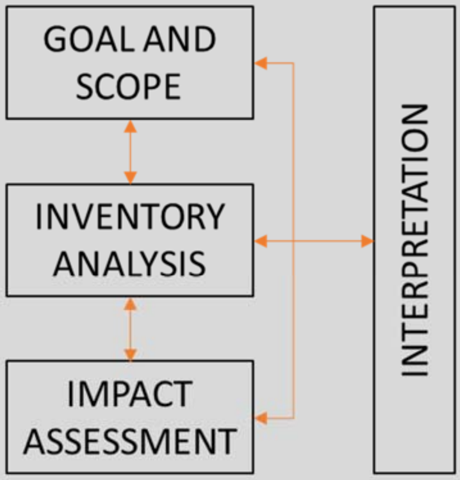
Laser profilometer (up); SCRIM (down)

During monitoring, road surface properties such as skid resistance and macrotexture were determined through the SCRIM device (Sideways force Coefficient Routine Investigation Machine) and laser profilometer respectively. Besides, coring samples were extracted from the road surface to assess the bitumen, aggregates and polymer real content and the structural capacity of the road as related to layer stiffness and strength. Visual inspections were also carried out as part of the study in order to detect any damage in the pavement surface as a result of the actions of traffic loads and weather conditions.

Environmental and economic validation

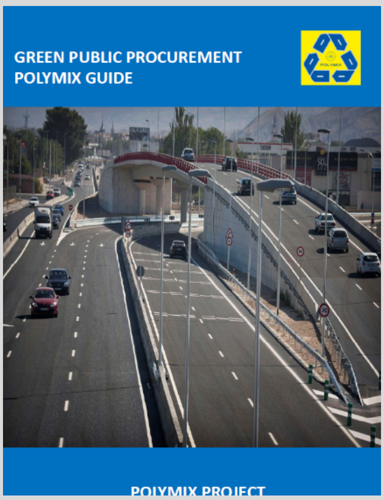
On the one hand, the environmental assessment of the POLYMIX technology was carried out through a Life Cycle Assessment following the methodology recommended by the International standard ISO 14040-43. The environmental impact of the four POLYMIX mixtures was compared with the impact caused by conventional mixes (without the addition of polymer waste).

The economic feasibility of the modified asphalt mixes was also carried out by considering the cost of the new mixes, the production process and the benefits derived from the use of the new mixes. For this purpose the tool Alizé LCPC software was used.



ISO 14040 Life Cycle Assessment Framework

Steps for the future replication of POLYMIX technology



GPP POLYMIX guide

In order to boost the use of eco-friendly asphalt mixes, a methodology was developed to provide information about the technical specifications and requirements that could be included in Green Public Procurement processes. Although the methodology was developed on the basis of the Spanish scenario, the adaptation to other European countries was also analysed. A case study with POLYMIX technology is presented in the guideline "Green Public Procurement. POLYMIX guide" (available at the website).

In order to give a clear idea of the potential for the replicability and commercial application of the technology, a SWOT analysis of POLYMIX technology was carried out where main threats and drivers of the technology were identified.

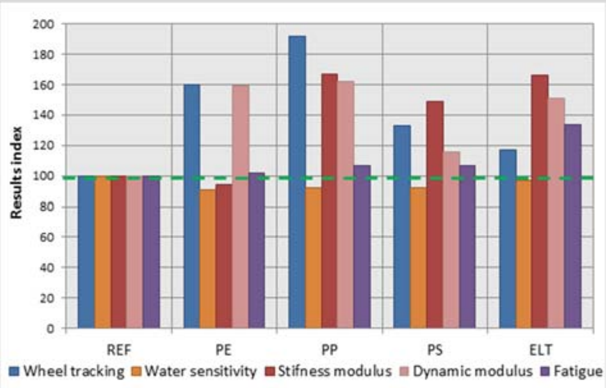
RESULTS

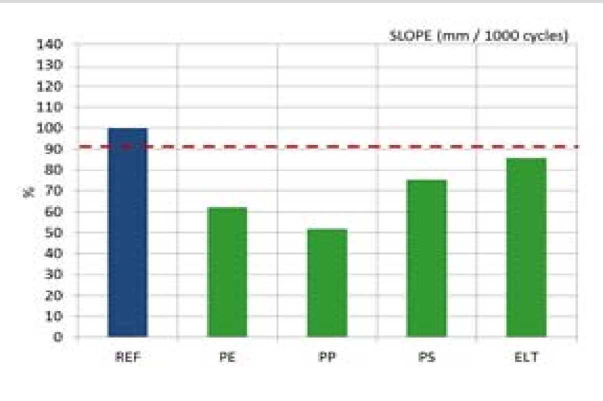
Design and characterization of POLYMIX mixes

According to the results obtained during the design and characterization of the new mixes, it was concluded that all of them met the technical requirements currently set out in the Spanish normative for their use in road construction both as wearing and base course.

From the available samples, the optimal polymer waste to be used as asphalt mix modifier were polyethylene from containers, polypropylene from caps and polystyrene from hangers. Moreover, the optimal percentage was found to be 1%.

In addition, and comparing to the reference, the samples designed that incorporated polymer waste present, in all cases, better resistance to plastic deformation (wheel tracking test) and higher dynamic modulus while maintaining fatigue resilience.





Mechanical characterization results (up)
Wheel tracking test results (down)

Rubber from ELT

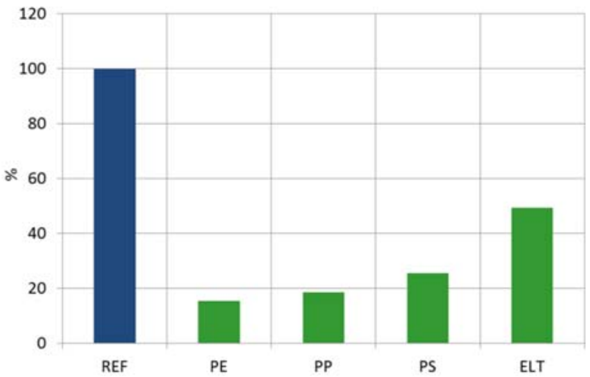
PP from caps

PE from containers

PS from hangers

Technical, environmental and economic validation

Main result obtained from the monitoring activity is the confirmation, in agreement with the laboratory results, of the higher resistance of POLYMIX asphalt mixes to rutting. This is expected to positively impact on the durability of the asphalt mixture.



Wheel tracking test results

Asphalt paver

Compaction

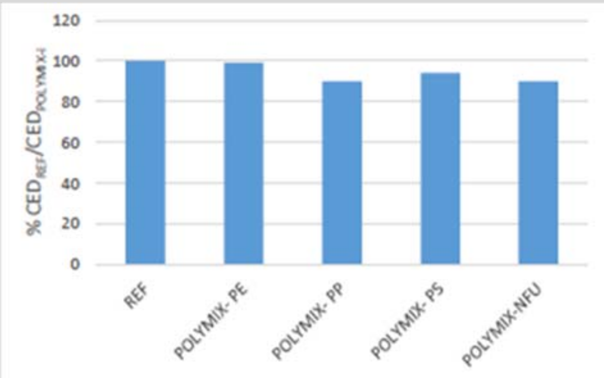
Core samples extraction

On the other hand, road surface properties such as skid resistance, macrotexture and longitudinal and transverse surface regularity were measured during the monitoring of the road. In general, no significant variations between the mixtures were found. All sections, including the reference, had a similar behaviour and therefore such variations are not dependent of the addition of recycled polymer to the asphalt mixture.

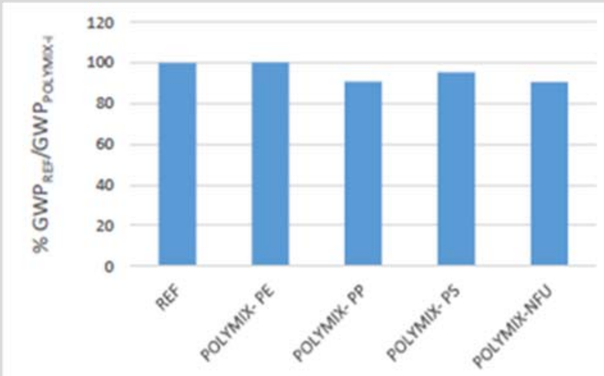
In addition to the technical validation, the economic feasibility was checked by analysing the construction costs of the new mixes and comparing these costs with conventional asphalt mixes. POLYMIX mixes were found to be more expensive than conventional mixes due to the higher cost of recycled polymer as regards to natural aggregates. However, due to the better performance of POLYMIX mixes, the possibility to reduce the thickness of the asphalt layer was studied with Alizé LCPC. Polymer modified asphalt mixes that incorporated polypropylene or rubber from ELT were found to be more cost-effective than conventional mixes. Polystyrene modified asphalt mixture was just a bit more expensive.

Finally, the potential environmental impact of the technology was evaluated. This assessment was carried out through a Life Cycle Assessment following the methodology recommended by the International standard ISO 14040-43. All input and output values for the individual processes in the production and on-site implementation of the asphalt mixes were taken into account.

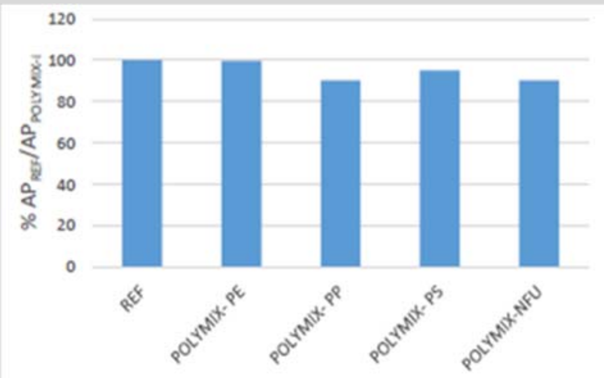
Comparison of the environmental impact of the different asphalt mixes developed shows that, on the 4 category impact analysed, POLYMIX mixtures present better environmental performance. Therefore, the reuse and exploitation of recycled plastic in bituminous mixes not only does not increase the environmental impact of the final product, but in some cases it is even reduced.



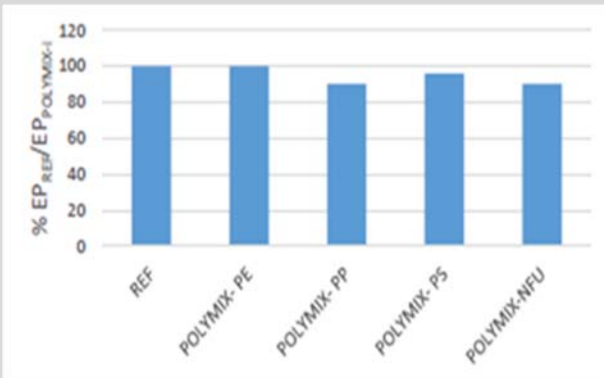
Cumulative Energy Demand



Global Warming Potential



Acidification potential



Eutrophication Potential

LONG-TERM BENEFITS

The increment of freight traffic and harsh climatic conditions in all European countries due to the climate change is increasing the need of maintenance inversions in old EU Member States. Conventional materials lack cost-efficiency when used in high stressed roads.

One of the main features of POLYMIX, that is common for all type of polymers studied in this project, is its better resistance to plastic deformation (rutting resistance) comparing with the reference. This characteristic makes these bituminous mixes especially suitable when high extreme temperatures and high weight traffic are combined. Therefore, the use of this technology by road asset managers will result in less maintenance costs.

It should be also mentioned that according to the monitoring results, most of the PS was dissolved in the bitumen and an increase of the total bitumen content in the POLYMIX-PS mixture was observed. Because of this, the possibility to reduce the amount of virgin bitumen needed is expected. If this is confirmed, the cost of POLYMIX-PS would be significantly reduced.

POLYMIX pilot road

On the other hand, the increase in the recycling of plastic waste has the following environmental benefits:

- Recycling of waste

During the construction of one km of a wearing course, around 1296 Tn. of the bituminous mixture are produced, laid down and compacted. Up to 10Tn of polymer waste might be recycled per km of road.

This will encourage the development of more efficient plastic waste collection schemes to provide a stable supply of material. Waste plastic companies will not prepare sorting and production of recycled plastic if they have no security for a stable supply. New alternatives for the reuse of recycled materials increase their demand and the growth of business interests.

- Resource savings

The volume of polymer waste used in each mixture replaced the same volume of natural aggregates. A total amount of around 60 Tn of aggregates were saved during the construction of the pilot road.

- Emission reductions

The recycling of the polymer waste (PS, ELTs, PE and PP) implies a reduction of the same amount of polymer waste that is sent to landfills or burned in an incineration plant.

- 253 g/Kg CO_2 emissions are generated by landfill disposal.
- From 673 g/Kg to 4605 g/kg [1], CO_2 emissions are produced by incineration, depending on the efficiency and the source of electricity and heat that the incineration of plastics is replacing.

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[1] Plastic waste as a fuel – CO_2-neutral or not?. http://www.ecolateral.org/plasticasafueirschem0709.pdf

CONTRIBUTION TO EUROPEAN POLICY

POLYMIX technology will contribute to several current regulations on the treatment of polymer wastes at European and National or Regional level. The proposal of new alternatives, such as the technology presented in this project, for reusing polymer wastes, will help Member States to comply with the following regulations.

- EU landfill directive (1999/31/EC): the EU's landfill directive is not focused on plastics, but establishes the objectives for biodegradable municipal waste diversification. This directive prohibits the dumping of tyres in landfills, either whole or shredded.
- EU Packaging waste directive (2004/12/EC): this Directive deals with the plastic wastes from packaging, among other things, and obliges Member States to recover at least from 50 to 60% and recycle at least 25 to 45% of all the sold packages.
- Waste framework directive (2008/98/EC): the waste framework directive obliges countries to adopt the necessary measures to reuse or recycle at least 50% of plastic, paper, metal and glass from the household wastes by 2020.
- The Directive on the Landfill of waste (1999/31/EC) laid down a ban of the disposal of whole tyres by 2003 and of shredded tyres by 2006.
- EU Directive on End-Of-Life Vehicles (2000/53/CE): this Directive does not refer directly to a plastics recycling obligation. However, the directive defines a global plan for recycling and reuse of 80% by 2006 and 95% of ELV wastes by 2015.

In addition POLYMIX contributes to the achievement of the European environmental objectives established by Europe 2020 strategy in relation to sustainable growth by helping to:

- Build a more competitive low-carbon economy that makes efficient, sustainable use of resources.
- Protect the environment and reduce emissions
- Capitalise on European leadership in developing new green technologies and production methods.

The reduction of CO_2 emissions along with the decrease of resource intensity are benefits of the project also in accordance with the aims of Europe 2020 flagship "Resource-efficient Europe" that intends to support the shift towards a resource-efficient, low-carbon economy.