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Self-healing maintenance road techniques for improving circular economy: Preliminary results of the Environmental Footprint

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Introduction & Background

Self-healing roads are a new generation of pavements whose materials are capable to recover their original properties after cracking appears. This innovative technology aims to reduce the consumption of natural resources and energy in the whole life-cycle of roads, due to the potential achievement of increasing their lifespan compared to traditional maintenance operations.

Several previous tests have demonstrated the possibility of achieving new asphalt mixtures that could be the self-healed by means of microwaves or induction when the pavement reaches a certain degree of deterioration, so the traditional maintenance technique could be postponed [1-2]. Hence, this novel technique would go in line with the circular economy.

Figure 1 shows an schematic overview of the process.

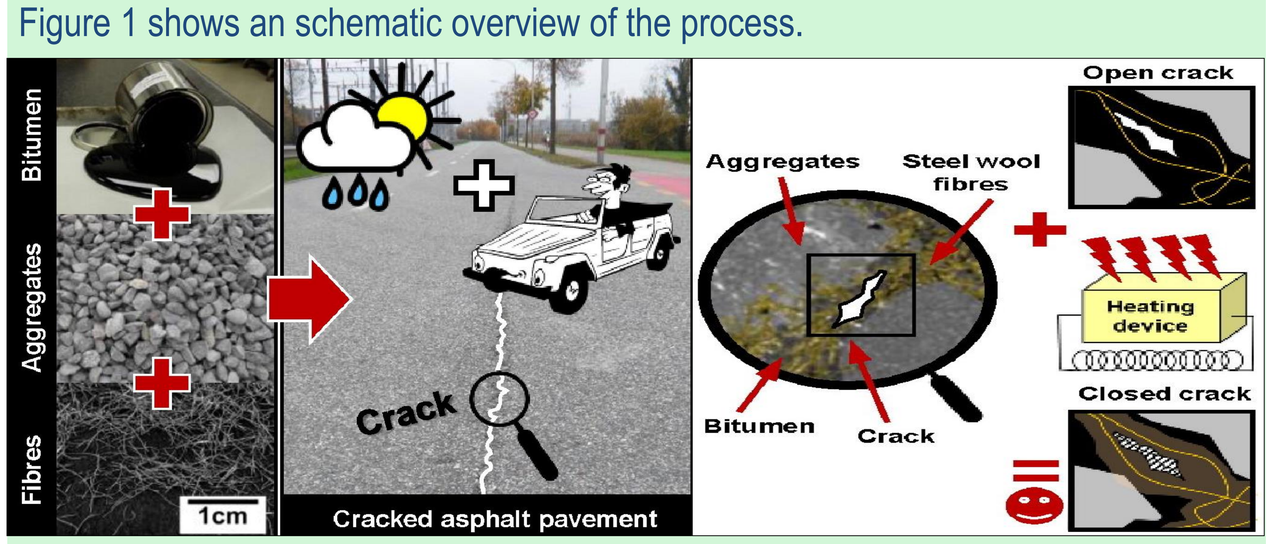

***Figure 1**. Self-healing process scheme with steel fibres (adaptation from [2]).*

As self-healing technology is still under study, there is a lack of rigorous environmental and economic studies. The objective of this study is the quantification of the advantages and shortcomings of this novel technique when compared to traditional rehabilitation activities, since it is currently one of the priority research lines for paving materials nowadays.

Materials & Methods

Life cycle inventory has been compiled by the different tasks to be carried out along the years. Table shows these tasks and the main energy and raw materials inputs for each technique. Then, conventional rehabilitation *versus* self-healing road maintenance techniques are presented.

Environmental Footprint (EF) methodology has been applied, considering '$m^2 \cdot year$' as the unit of analysis.

Year	Conventional	Self-healing
0	**Road construction** *Bitumen, aggregates, diesel (machinery, plants), transport (materials)*	**Road construction** *Bitumen, aggregates, steel fibres, diesel (machinery, plants), transport (materials)*
8		**Microwaves treatment** *Diesel (machinery)*
10	**Renovation with slurry** *Bitumen, aggregates, diesel (machinery), transport (materials)*	
15	**Milling** *Bitumen, aggregates, diesel (machinery), transport (materials)*	**Microwaves treatment** *Diesel (machinery)*
21		**Milling** *Bitumen, aggregates, diesel (machinery), transport (materials)*
23	**Rehabilitation with recycling (10% RAP)** *Bitumen, aggregates, RAP (Reclaimed Asphalt Pavement), diesel (machinery), transport (materials)*	
29		**Microwaves treatment** *Diesel (machinery)*
30	**Road dismantling** *Diesel (machinery), transport (materials)*	
36		**Microwaves treatment** *Diesel (machinery)*
42		**Road dismantling** *Diesel (machinery), transport (materials)*

Results

Figures 2 and 3 shows the relative EF results of the conventional and self-healing maintenance techniques by task, while Figure 4 shows the comparative between these two techniques along the entire life cycle.

The impact categories acronyms are the following: CC (Climate Change), OD (Ozone Depletion), IR (Ionising Radiation), PO (Photochemical Ozone Formation), RI (Respiratory Inorganics) HHnc (Human Toxicity non-cancer,), HHc (Human Toxicity cancer), AC (Acidification), EuF (Freshwater Eutrophication), EuM (Marine Eutrophication), EuT (Terrestrial Eutrophication), EcF (Freshwater Ecotoxicity), LU (Land Use), WS (Water Scarcity), Ren (Resource Depletion, energy) and Rmm (Resource Depletion, mineral and metals).

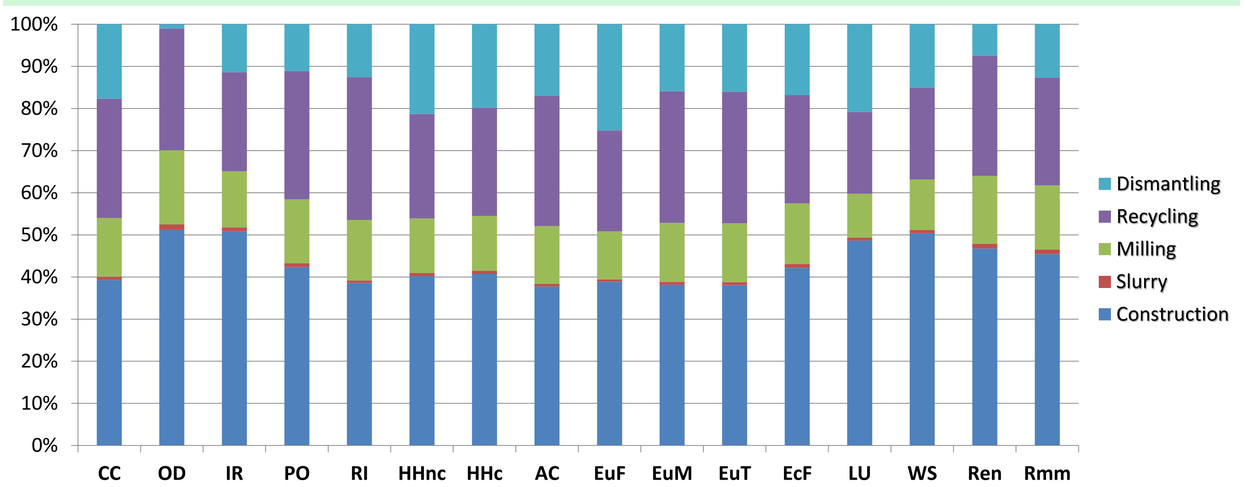

***Figure 2.** EF results of the conventional rehabilitation technique of roads, by task.*

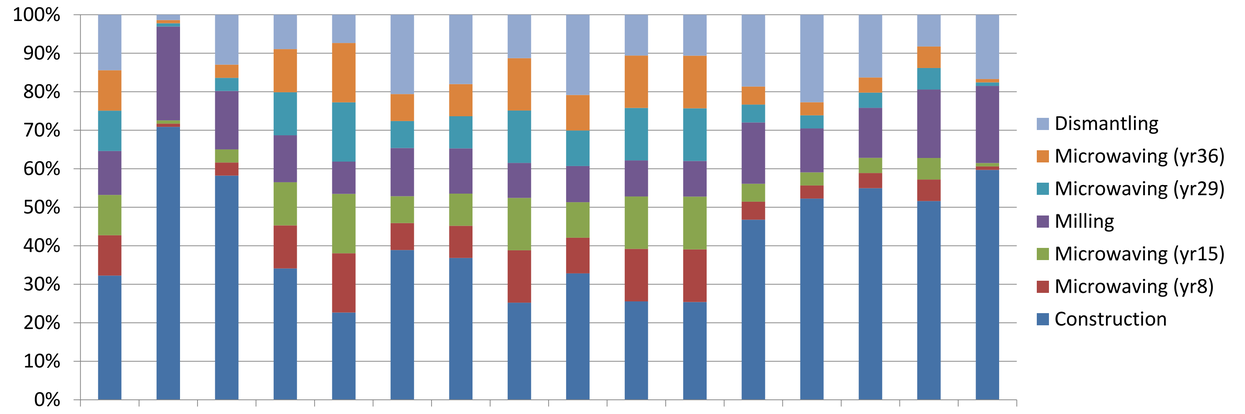

***Figure 3.** EF results of the self-healing rehabilitation technique of roads, by task.*

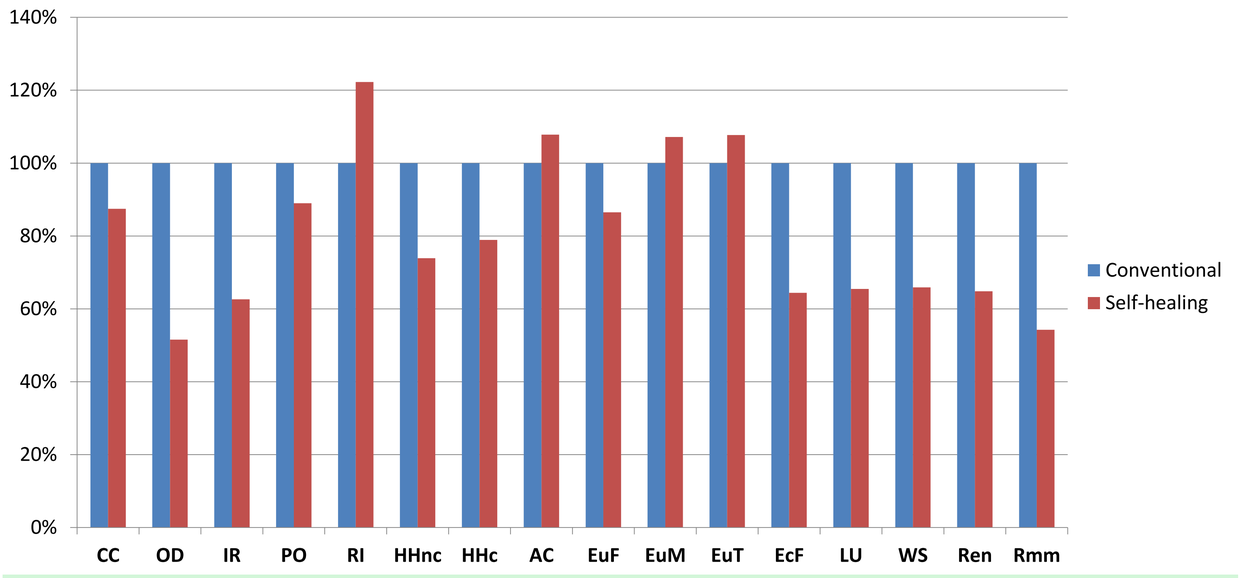

***Figure 4.** Comparative EF of conventional vs self-healing rehabilitation technique of roads.*

Discussion & conclusions

Construction phase is the most pollutant activity for both study cases as well as end-of-life dismantling tasks. It appears the self-healing technique chosen (steel slag + microwave heating) reduces the majority of the impact categories compared to roads maintained with conventional techniques. In fact, climate change impact is reduced between 10-15% (as hypothesis), while the acquisition of extra abiotic materials is reduced by 50%, improving effectively the circular economy.

References

[1] Gallego J, del Val MA, Contreras V, Páez A. Heating asphalt mixtures with microwaves to promote self-healing, *Construction and Building Materials*, Vol 1, 2013, pp. 1-4. https://doi.org/10.1016/j.conbuildmat.2012.12.007 .
[2] Norambuena-Contreras J, García A. Self-healing of asphalt mixture by microwave and induction heating, *Materials & Design*, Vol 16, 2016, pp 404-414. https://doi.org/10.1016/j.matdes.2016.05.095.

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