



## End-of-Life Tyres applications in civil, geotechnical and environmental engineering: A brief overview

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ARTICLE INFO	ABSTRACT
<p><b>Original Review Article</b> Received on April 15, 2025 Revised on April 20, 2025 Accepted on May 10, 2025 Published on May 15, 2025</p> <p><b>Article Author</b> Antonella Dimotta</p> <p><b>Corresponding Author Email</b> <a href="mailto:a.dimotta.eeseemr@gmail.com">a.dimotta.eeseemr@gmail.com</a></p>	<p>The ever-growing and urgent need to be able to tackle and manage the well-known negative impacts of the so-called <i>black pollution</i> - generated by End-of-Life Tyres (ELTs) - has triggered virtuous and interesting mechanisms aimed at minimizing the abovementioned pollution and further effects by focusing on the End-of-Life Tyres management and applications. This paper presents a brief overview of the various applications of the ELTs in two different scopes of engineering, such as civil and environmental, including also geotechnical scope, to give an updated technical view of ELTs fate worldwide.</p>
PUBLICATION INFO	KEYWORDS
<p>International Journal of Agricultural Invention (IJAI) <b>RNI:</b> UPENG/2016/70091 <b>ISSN:</b> 2456-1797 (P) <b>Vol.:</b> 10, <b>Issue:</b> 1, <b>Pages:</b> 194-199 <b>Journal Homepage URL</b> <a href="http://agriinventionjournal.com/">http://agriinventionjournal.com/</a> <b>DOI:</b> 10.46492/IJAI/2025.10.1.24</p>	<p>End-of-Life Tyres, Environmental Pollution, Elts-Derived Materials, Geotechnical Properties, Engineering Applications</p>

### HOW TO CITE THIS ARTICLE

Dimotta, A. (2025) End-of-Life Tyres applications in civil, geotechnical and environmental engineering: A brief overview, *International Journal of Agricultural Invention*, 10(1): 194-199. DOI: 10.46492/IJAI/2025.10.1.24

The strong interest in reducing the serious environmental impact of the End-of-Life Tyres as a waste has generated virtuous reasoning on potential uses and applications in different scopes worldwide. Such virtuous goal has been reached by linking ELT products (after specific treatments and management operations) with engineering scope, to allow End-of-life tyres a new Life Cycle. The role of engineering in giving new life to a product that, before this process, would have been considered less than a waste, works out well in heterogeneous scopes and contexts in terms of proficient and productive usage. Civil and environmental engineering represent, respectively, a great source of applications and usage of such products, since waste tyres are characterized by well-defined

features (mechanical and physiochemical ones). In addition, this frame can also include the importance of LCA of ELTs. Finally, to better summarize the present paper, it has been divided into the following three main sections:

- End-of-Life Tyres as a waste
- ELTs engineering applications: civil, geotechnical and environmental scopes
- Conclusions

### Materials and Methods

Such a brief overview aims to focus on the great importance and significance of considering how and how much environment-based response can really help to tackle ever growing energy-based

demand by finding out new routes to be investigated, as potential and sustainable outputs in accordance with the European Targets by 2030 until 2050. For this purpose, the present research work was divided into two macro-sections, as follows:

### 1<sup>st</sup> Section - Section (A)

Literature review about ELTs-derived materials and their applications in three engineering scopes, such as civil, geotechnical and environmental. Literature review was carried out by focusing on the recent global outcomes.

### 2<sup>nd</sup> Section – Section (B)

Brief overview of the different engineering applications of End-of-Life Tyres as a new product output and conclusions.

#### **End-of-Life Tyres (ELTs) and Engineering Applications ELTs as a Waste and a Focus on Environmental Impact**

End-of-Life Tyres represent a relevant portion of End-of-Life Vehicles (ELVs) (Gigli *et al.*, 2019). As reported by (Gigli *et al.*, 2019), nowadays, end-of-life vehicles (ELVs) constitute a massive waste source in Europe, even if ELV recycling is a priority of Union waste legislation, as underlined in the ELV European Directive, 2000/53/EC (European Commission, 2000). Every year, about 3.4 million tons of old tires are disposed of in Europe, most being dumped or sent to landfill, in direct contravention of the EU rules banning landfilling of both whole and shredded tyres (EASME, 2015; ETRMA, 2015; European Directive, 2000). Moreover, in terms of waste classification, textile fiber, which is a relevant portion of the ELT material, makes ELT a *special waste* (European Waste Catalogue – EWC code 19.12.08). Thus, the main problem related to textile fiber is its contamination with rubber which does not allow obtaining a pure product economically and qualitatively useable (Gigli *et al.*, 2019). In relation to the main phases of the management of this special waste, as mentioned in Gigli *et al.*'s research work (2019), the treatment and the recovery process of ELTs is aimed at recovering triturated rubber in various sizes and types, which represents the main portion of the ELT material (Ramarad *et al.*, 2015; Schnubel, 2014; WBCSD, 2010).

Focusing on gaseous and solid pollutants (CO, CO<sub>2</sub>, NO<sub>x</sub>, and SO<sub>2</sub>) emitted by particular ELT treatment typologies is one of the main steps to understand and identify the severe environmental impacts negatively affecting the Earth-ecosystems and their services. Regarding the management of ELTs, it has been observed that it has become a crucial issue worldwide due to the increasing number of vehicles circulating in the road network and to the crucial role that mobility has assumed in modern society development (Landi *et al.*, 2018). As described by (Clauzade *et al.*, 2010), to better focus on a potential evaluation method of environmental impact, it was based on the reference methodological principles for studies related to the management of household waste. Therefore, obtaining an environmental assessment for the various recovery methods was established by adding the following data:

- The impacts generated by collecting and preparing the ELT.
- The avoided impacts by the fact of replacing traditional products with ELT.

As an example, in the case of cement works, using tyres as a replacement for traditional fuels makes it possible to: avoid the extraction and preparation stages needed for these traditional fuels, the supply process for these traditional fuels and the shredding of solid fuels; replace the fossil origin CO<sub>2</sub> emissions caused by the combustion of traditional fuels with fossil- origin and biomass CO<sub>2</sub> caused by the combustion of used tyres; recover the steel contained in the ELT.

#### **ELTs-derived Materials and Engineering Applications**

As reported by (Zanetti *et al.*, 2021), crumb rubber (CR) derived from grinding end-of-life tyres (ELTs) may be successfully used as a bitumen modifier or as a supplementary component in the production of bituminous mixtures employed for the construction and maintenance of road pavements. However, CRs deriving from different sources and production processes yield effects on performance of corresponding paving mixtures under traffic loading and on gaseous emissions produced during lying on site which may change considerably depending upon their physical and chemical properties in terms of material quality (Zanetti *et al.*, 2021).

## Civil Engineering Scope

The structural and civil engineering sector has considered as a great way of generating permanent progress in engineering and circular economy by implementing material circularity and focusing on specific materials, such as bitumen, concrete and steel in land and transportation infrastructure, in order to improve the growing request of new buildings and infrastructural project across the planet. Such a new vision of the linkage between economy and civil engineering scope can be seen as an opportunity to consider the material re-circulation potential of construction materials (Mhatre *et al.*, 2021). Thus, this interesting contribution in the built environment could even implement the potential of economic resources and their stability.

## Geotechnical Engineering Scope

As civil engineering evidence, the ELTs-derived material, such as the rubber granulates, it has been demonstrated that the rubber granulates as a lightweight backfill material in retaining walls (Contreras-Marín *et al.*, 2021). Various tests have been performed to provide specific information on the mechanical and physical properties of a detailed range of particle sizes smaller than 12 mm, with six different particle size distributions (S1: 0.0–0.8 mm/ S2: 0.6–2.0 mm/ S3: 2.0–4.0 mm/ S4: 2.0–7.0 mm/ S5: 90% 2.0–7.0 mm + 10% 0.6–2.0 mm/ S6: 50% 2.0–7.0 mm + 50% 0.6–2.0 mm). The density and unit weight, compaction energy, compressibility, shear strength, and deformability have been evaluated to determine their performance. In terms of geotechnical characteristic values, the geotechnical parameters have been estimated according to Eurocode 7 (Contreras- Marín *et al.*, 2021). Also, in geotechnical scope, a series of static and cyclic laboratory tests were performed to contribute to managing and preventing the burial of a part of hazardous waste produced during the recycling process of worn tires. In addition, repeated load triaxial (RLT) tests under various stress levels were conducted after the addition of different contents of waste tyre textile fibers (WTTFs) to a sandy soil. Such series of static and cyclic laboratory tests showed that fiber inclusion enhances all geotechnical properties of the soil under static state (Abbaspour *et al.*, 2019; 2020).

Moreover, as earlier demonstrated, a possible use of waste tyre textile fibers (WTTFs) as spread reinforcement in cementitious composites has been recently investigated (Caggiano *et al.*, 2017).

## Environmental Engineering Scope

As stated by (Lapkovskis *et al.*, 2019), proper recycling and secondary reuse of end-of-life tyres (ELTs) remain an important issue for many regions. Devulcanized crumb rubber as a product of ELT recycling could be used for very different applications, including site remediation by spilled oil products. A development of new bio- based composite material containing devulcanized crumb rubber and cenospheres is suggested. Designed bio-based composite can be used as an oil spill adsorbent, material for civil engineering, and as a raw material for further modification by introduction of ferromagnetic components (Lapkovskis *et al.*, 2018).

Homogenised peat with peat content  $14.0 \pm 1.5$  wt%, particle size 0.01-0.5 mm used as a natural bio-based binder. Devulcanised crumb rubber particle size 1.0-4.0 mm was used as a porous substrate. Designed compositions contained 5, 10, 15, 20 wt% (before drying) of devulcanised crumb rubber. Cenospheres have duplex function for designed composite: lightweight additive that makes final product floatable, and at the same time minimizes shrinkage of dried product (Ranjbar and Kuenzel, 2017). It was found that devulcanised crumb rubber reduces density of final composite and adding open porosity. Developed bio-based composites could be manufactured in granules by drum granulation technique for further environmental applications (Jones and Brischke, 2017). Formability and apparent density of bio-based composite are studied. Chemical and thermal stability are very important properties for oil-spill adsorbent for further regeneration of the used materials (Lapkovskis *et al.*, 2019). Another ELT-derived material was investigated: activated carbon was prepared from end-of-life tires, and its surface functional groups were enhanced by wet chemical oxidation using nitric acid (Danmaliki and Saleh, 2016). The carbonization and activation temperatures were optimized.

The obtained material was characterized by using a Brunauer–Emmett–Teller surface area analyzer, a Fourier transform infrared spectroscope, and a scanning electron microscope coupled with an energy dispersive spectroscope. It was evaluated for adsorptive desulfurization of dibenzothiophene (DBT) in a model fuel (Danmaliki and Saleh, 2016). As reported by (Danmaliki and Saleh, 2016), the use of adsorbents in adsorptive desulfurization (ADS) has been the focus of researchers because of its mild operating conditions. The current area of research focuses on the development of cost-effective, efficient and reliable adsorbent materials to reduce the sulfur content of the fuel (Ali, 2012, Ali and Gupta, 2006, Ali *et al.*, 2012). Finally, environmental applications of ELTs have registered numerous usages of the ELTs-derived materials as adsorbents applied in wastewater treatment plants, such as activated carbon (Özbaş *et al.*, 2019; Macías-García *et al.*, 2019).

### ELT Final Products and Usage

The ELT final products derived from recycled tyre rubber are being used in the following ways and scopes:

- New tyres
- Tyre-derived fuel
- Molded rubber products
- Agricultural uses
- Sport and recreational applications
- Rubber-modified asphalt applications.

Also, a very interesting usage of ELTs was found in the following applications:

- Boat protection (Abdul-Kader and Haque, 2011)
- Conveyor belts (Aziz *et al.*, 2018)
- Footwear industry (Machin *et al.*, 2017)
- Gardening (Figlali *et al.*, 2015; Singh *et al.*, 2019; Zorpas, 2020)
- Lawn grounds (Symeonides *et al.*, 2019)
- Packing material (Thomas and Gupta, 2015; Heidari and Younesi, 2020)
- Thermal and acoustic isolation (Abdul-Kader and Haque, 2011; Asaro *et al.*, 2018; Araujo-Morera *et al.*, 2019)
- Vibration reduction on railway tracks (Sol-Sánchez *et al.*, 2014)
- Wagon wheels (Girskas and Nagrockiene, 2017).

### Results and Conclusion

The resulting frame can be considered as an instant photo of the current research on this context. Thus, the present overview focuses on the main engineering applications and usage of ELTs by including a brief insight into ELTs-derived materials and correlated environmental impact, in terms of waste. A short note was also included about a potential (Life Cycle Assessment) LCA method to be applied for specific environmental evaluations and assessments in this context. The EU targets by 2030 until 2050 (EU Agenda, 2030) impose a great sustainable vision and “ratio” to be applied on this planet to improve the ecosystems health including the human one and their services and, at the same time, to guarantee a sustainable approach in the future. Civil and environmental engineering scopes are trying to apply great and smarter reasonings and consequent argumentations aimed at giving a useful and helpful response to the urgent needs of this planet. Recycling and reuse of ELTs can be an important binomial for maintaining a constant equilibrium in terms of entropy system worldwide towards the well-known sustainable development under the environmental and economical viewpoint with a particular attention on circular economy. Finally, the present study could be implemented by further focuses aimed at offering an ever-increasing updated framework on new research topics and global challenges.

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