Application of wax-based emulsions from the pyrolysis of plastic waste in soils stabilization prior to road construction

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INTRODUCTION. One of the main conditions for the functioning of a thriving economy is a well-developed road infrastructure. In the years 2004-2020, over 5,000 km of roads and highways were built in Poland. Currently, when building roads, before laying an asphalt or concrete surface, the ground that is the basis of the road under construction must be compacted and stabilized. There are two basic methods of soil stabilization: in situ and in a stationary node (ex-situ). The method of performing stabilization in place (in-situ) is the most frequently used method due to its convenience and lower price. The most popular type of binder for stabilization is a hydraulic binder (most often cement and various ashes). Such stabilization is performed at a depth of 10-50 cm, achieving the desired load-bearing parameters. In order to improve them, various chemical additives for stabilization are often used, such as ion exchange compounds, additives based on sulfuric acid, additives based on vinyl polymers or even organic additives using lignosulfonates. Unfortunately, the use of such additives is associated with much greater costs, so there is a need for cheaper and equally effective alternatives, which at the same time do not pose more environmental risks. The win-win situation would be for instance recycling the problematic waste-based materials that on one hand are landfilled or impossible to recycle and on the other hand cause t problems for the waste producers. Therefore, an interesting issue is the production of stabilization additives from various types of waste materials. The research on innovative plastic waste-based binders has been carried out so far at the Construction Company "WACIŃSKI" via the project: *"Development and implementation of effective stabilizing mixtures for the foundation of road surfaces using fly ashes from the coal-based energy sector in Gdansk" (Regional Development Programme of Pomorskie Voivodeship/ Action 1.1.1 Expansion via innovations)*, https://www.wacinski.pl/projekty-ue/. This construction company as partner of IMP PAN, applied and tested plastic waste products in soil stabilisation, that were prepared by IMP PAN and Janpol Technologie LtD. (https://piroliza.com.pl/).

Fig. 1. Visual effect of waste-based stabilizers affecting the soil sealing influencing its frost resistance

METHODOLOGY. Emulsions of post-pyrolytic waxes from the pyrolysis of waste polyolefins were prepared using the following plastic waste fractions: (1) HDPE (High Density PolyEthylene), (2) post-separated plastic high-calorific fraction (RDF - Refuse Derived Fuel), (3) car tires, (4) clean PE foil. Pyrolysed products were supplied both by the company JANPOL Technologie Ltd and in parallel by IMP PAN. Pyrolysis is not widely adopted yet due to environmental and legislative reasons. The following soil mechanical parameters were tested at the Construction Company "WACIŃSKI": (1) compressive strength (CS) after 7 days and after 28 days, (2) water absorption (WA) after 4h and 24h, expressed as the amount of water absorbed by the soil and shown in% (g H_2O/ g dry weight of soil) and (3) frost resistance (FR) as compressive strength after 14 freezing cycles, related to the initial compressive strength after 28 days, expressed as % of the initial strength. These parameters are commonly when planning the stabilisation and come from the national standards PN-EN 13282-1:2013-07, where all main components are specified, whereas minor additional constituents (not more that 10% w/w in total) and additives (not more than 1% w/w in total) can be added.

Fig. 2. Manual application of liquid soil stabilizers (emulsion based on plastic waste pyrolysis products - waxes).

RESULTS. The laboratory mechanical tests confirms the positive influence of these waste products on some parameters of stabilized soil (eg. compressive strength and sealing). The positive effect of selected additives has been observed for both cohesive (clays, silts) and non-cohesive soils (sands, gravels). Each of these plastic waste post-pyrolytic wax/water emulsions have been tested as a stand-alone stabilizer (+5 treatments and the analysis of full set of 3 mentioned above key parameters) as well as hybrids with other waste additives (+10 treatments and the analysis of full set of 3 mentioned above key parameters)). Emulsions from clean PE foil show the best effect: **37%** increase in compression strength for cohesive soils **(clay)** and **55%** increase for non-cohesive soils **(sand)**, then followed by RDF-based emulsions (**33%** more compression strength for **clay** and **42%** more for **sands**) and HDPE-based emulsions (**31%** more for **clay**, **16%** more for **sand**). In addition, the sealing parameter, directly improving the frost resistance (based on ability to reduce water absorption and soaking) having a direct effect on capillary forces was also visibly improved as for **sands** the frost resistance ranged between **70% and 93%** (with 46% for the control sample), which is closely related to both low short (4h) and long-term (24h) water absorption (**0.35%-2%** g water/ g soil dry matter for short-term with control at 6% and **3-8.%** g water/ g soil dry matter for long-term with control at 10%) for these soils amended with stabilizers.

The positive result of this research allows us to hope for new additions to the stabilization of waste origin and that they will contribute to the improvement of the quality of road infrastructure along with a neutral impact on the soil environment and positive impact on plastic waste upcycling. The areas of further attention are (1) obtaining the permits for the potential manufacturer for processing the plastic waste into pyrolysis products or importing them, emulsification and purification/ stabilisation, (2) products recognition and approval by national certification for hydraulic soil binders, (3) benchmarking and parity with conventional soil stabilization products. Environmental risk considerations are not the main concern as the potential amount of plastic waste wax in the form of water emulsion, introduced to the soil subsurface is less than **0.5 kg/ m^2**, and only insignificant amounts (below the national limits) of heavy metals and organic contaminants were found in the leachates.

This proposal is in line with the objectives of the **Circular Economy Action Plan**, which focuses on the sectors using a high amount of resources, where the potential for improvement is high, like plastics, textiles, construction and buildings. The Plan even has a separate Plastics policy. The proposal is also coherent with the **EU Green Deal**, namely it supports reduction of net greenhouse gasses emissions by 2050 and helps decoupling the economic growth from resource use by upcycling plastic waste products in roads. This action is in line with the **Waste Framework Directive**, where EU countries are obliged among others: for re-use and the recycling of municipal waste to a minimum of 55 %, 60% and 65% by weight by 2025, 2030 and 2035, respectively. The Directive also requires that waste will be managed without endangering human health or harming the environment, without risk to water, air, soil, plants or animals. The Directive criteria also specify when certain wastes cease to be waste and become a product, or a secondary raw material.

READINESS. The Technology Readiness Level (TRL) of this technology is around 6-7; the laboratory tests are finished and the real scale roadworks are to be started soon. Still some technical problems eg. development of an automatic dosage system for emulsions are to be solved (Fig. 2 shows manual way of emulsion application for the research reasons). The technology is closely related to the Integrated Solid Waste Management (ISWM) framework. As the intended use is for local and national roads construction, national and local authorities are responsible for decision-making and citizens (drivers) are the final users. The covered Waste System Elements are: plastic **waste treatment** via pyrolysis and **recycling** as post-pyrolytic products (waxes) purification and preparation of steady emulsions,. “Financial/ Economic” benefits are expected due to savings in no use of commercial additives and making revenue on waste utilisation. Whereas “Sociocultural”, “Institutional”, “Policy/ legal/ political” factors need to be considered if scaled out and applied in real scale.

ISWM Framework Positioning of the Case Story

Stakeholders: Citizens, Local Authorities

Waste System Elements: Waste treatment, Recycling, Reuse

Aspects: Technical, Environmental, Financial, Socio-cultural, Institutional, Policy/legal

Fig. 3. Mixing the applied novel stabilizers with soil using conventional technique.

Lessons learned:

- Plastic waste-based pyrolytic products such as waxes effectively influence on soil stability parameters (compression strength, sealing, frost resistance) prior to road construction,
- Pyrolysis is not yet widely applied to waste products due to legislative and environmental reasons, what can be a barrier for technology development,
- Limited cost of input substrates of waste products is expected as normally plastic waste would need to be utilised elsewhere, what in Poland nowadays costs ca. 500-1500 PLN/ t
- The economics of thermal destruction (pyrolysis) of RDF has to been taken into account,

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