Innovative Use of Household Plastic Waste in the Production of Paving Slabs: Results of An Experiment

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Abstract

Plastic waste is discarded after its useful life and becomes part of the global solid waste disposal problem. Its use in the construction of paving slabs to reduce waste and primary material consumption and associated impacts is gaining significant interest in the infrastructure industry. Road paving is under increasing public pressure to mitigate the negative impact on the environment. In this connection, there is a need for a meaningful method of recycling plastic waste.

This research examines the economic, environmental and other benefits of using plastic waste in the construction of sidewalks. Plastics such as polyethylene terephthalate, polypropylene, low-density polyethylene and high-density polyethylene were studied. It employed a survey of published literature as a research methodology, searched through Google Scholar, Scopus, Web of Science and Research Gate.

The results show the feasibility of using plastic waste in the construction of road surfaces to promote environmental friendliness and economy. However, it requires technical modifications. Tests show that adding a small amount of plastic waste to a mixture of paving slabs leads to an increase in compressive strength and other important characteristics. The crystalline phase of polyethylene in paving tiles can improve moisture resistance and adhesion properties, as well as increase thermal performance without increasing costs. The use of plastic waste in the construction of paving slabs will lead to a decrease in landfills in Kazakhstan. The materials can be used on pavings for pedestrians, as well as for bicycles lanes. This can also contribute to improving the sustainability and quality of road construction.

Keywords: Household waste, Polyethylene, Asphalt mixes, Bitumen, Road surfaces

Introduction

Plastics are an optimally cheap material and, due to their properties, are used in almost all areas. However, their disposal is a very labor-intensive and long process. Of the waste, plastic is the most problematic in terms of recycling due to the fact that it practically does not decompose and stays in tact up to millennia. Improper disposal of plastic waste can lead to leaching of plasticizers that can enter the food chain, which means that toxic substances enter the human body. They have other negative consequences, such as water pollution, disruption of flora and fauna, and clogging of sewer systems and drains, which can lead to flooding (Syrmanova et al., 2020; Tyliszczak et al., 2014).

The use of plastics is becoming increasingly popular in road construction, for example, in paving slabs. Road construction consumes a large amount of energy due to the rapid deterioration of the pavement infrastructure (paving slabs) and the significant number of raw materials consumed annually (Fialko et al., 2022). Therefore, the road construction industry requires innovative methods to increase sustainability by reducing energy consumption, while taking into account the conservation of natural resources and assistance in waste management. Thus, the solution to the plastic waste recycling problem lies in its use as a component in the production of asphalt roads. The main advantages of using plastics for road construction are the reduction in the accumulation of plastic waste, a significant reduction in costs, and the resistance of roads to rainwater (Babak et al., 2019; Chernets et al., 2008).

Nowadays, road surfaces are very flexible, consisting mainly of soil as a base course, foundation and surface layer. The thickness of each layer affects the characteristics of the pavement. The soil serves as the lowest layer (base), and the next layer must be of high quality, since it supports the pavement (Bolatbek et al., 2016). Noor and Muhammad (2022) provide an overview of the use of plastic waste in pavements and report that the use of waste plastic can improve physical performance (e.g. mechanical strength) and chemical compatibility.

To do this, one should first crush and then mix it with hot bitumen. The resulting mixture can be used for laying sidewalks. Yao *et al.* (2022) assessed the environmental and economic sustainability of the use of plastic waste as asphalt material. The results showed that this can reduce costs and greenhouse gas emissions. Abukhettala and Fall (2021) show that the use of plastic waste for road pavements, indicates that this may be useful in roads. Almeida *et al.* (2021) demonstrate that the inclusion of plastic waste is a promising solution for road infrastructure. This study takes place in the Akmola Region In Kazakhstan. As reported in the news portals (Khabar, 2020), Akmola Region has a lot of unregistered landfills with municipal solid waste (MSW). It was reported that there are about 130 landfills in this territory.

At the moment, there are 4 plants in Kazakhstan ("Caspi Bitum", "POCR", "Qazaq Bitum" and "Asphaltobeton-1") that produce road bitumen. The total volume of their production reaches about 1 million tons per year. However, this is not enough to satisfy domestic demand of the country (Senimdi Aqparat Kozi, 2022; Determination of the modulus of elasticity, 2015). Kazakhstan also initiated a protocol to increase the supply of Russian tar for the production of bitumen. Transportation of imported materials significantly increases the carbon footprint of local road materials.

This research aims to contribute to reduce landfills by extracting plastic waste and its further proper disposal.

Its objectives are:

1. To investigate the use of plastic waste in sidewalk construction.
2. To assess economic and environmental benefits of this recycling approach.
3. To determine the optimal plastic content in paving for maximum strength and cost-effectiveness.
4. To review existing literature on this method's feasibility.
5. To identify technical adjustments for using plastic in road construction.
6. To evaluate the properties of plastic-infused paving slabs.
7. To mitigate environmental impacts of plastic waste.
8. To understand Kazakhstan's road construction dynamics and carbon footprint.

Review of Literature

In modern society, many vital economic sectors have undergone a paradigm shift due to the widespread use of polymers, also known as plastics. These synthetic materials, which are non-biodegradable, can remain in the environment for about 4,500 years without significant degradation. The significant challenges posed by plastic waste for both current and future generations require a prudent solution. It is clear that while completely eradicating plastic is not realistic, prioritizing its recycling and repurposing is crucial.

Annually, 8.3 billion metric tons of polymers are manufactured globally (Gibb, 2019), with 70% being disposed of in landfills or marine environments, posing a serious environmental concern (Jambeck et al., 2015). This issue is particularly prevalent in developing countries, where outdated production methods and costly recycling practices are prevalent (Singh and Sharma, 2016). It is important to note that plastic waste makes up around 10-11% of all solid waste in landfills (Rochman et al., 2013; Sabirova et al., 2018). This has negative consequences for ecosystems and reduces the amount of uncontaminated land. Efforts have been made to utilize energy from these polymers through methods like incineration; nevertheless, their effectiveness is hindered by the existence of pollutants, prominently chlorinated entities, and heavy metal remnants (Geyer et al., 2017; Intharathirat and Abdul Salam, 2016). In this regard, a developing concept that's gaining popularity in academic circles is using plastic waste in the creation of structural materials, ensuring that the resulting product's integrity and quality are not compromised.

The incorporation of plastic waste into paving slabs offers a two-fold benefit: addressing the ever-mounting global plastic waste crisis and improving the properties of construction materials. As this research underscores the feasibility and advantages of such an integration, a comprehensive exploration of the existing literature on the subject is essential to position the present study within a broader academic context.

In the field of infrastructure and road construction, which are typically energy-intensive and have a substantial environmental impact, there has been a significant shift towards more sustainable practices through the integration of plastic waste. This change, particularly noticeable in the manufacturing of paving slabs and road pavements, provides an innovative method for managing plastic waste and shows potential for improving material properties and reducing environmental harm.

Vinodhkumar and Vinodhkumar (2022) highlighted that integrating specified plastic waste into paving slabs improves durability and strength. Moreover, Crispino et al. (2016) and Desyani et al. (2023) discovered that incorporating certain plastic waste types and the crystalline phase of polyethylene can improve the wear resistance, moisture resistance, adhesion properties, and thermal performance of paving slabs.

On the other hand, Noor and Muhammad (2022) highlight the potential advantages of incorporating plastic waste into road pavements. According to their study, blending crushed plastic waste with hot bitumen results in significant improvements in physical characteristics, such as mechanical strength and chemical compatibility. This blend has been shown to increase resistance to natural adversities. This viewpoint was shared by Abukhettala and Fall (2021) as well as Almeida et al. (2021). They observed the various advantages of integrating plastic waste into road pavements, including functional improvements and long-term sustainability.

Dadzie and Kaliluthin (2022) expanded on this discourse by studying the impact of different proportions of plastic waste in road materials. Their research found that increasing these proportions improved the material's resistance to wear and tear, particularly in severe weather conditions. Padasala et al. (2022) attributed the extended longevity of roads to the binding properties of polymers found in plastic, while Veropalumbo et al. (2023) emphasized the environmental benefits, such as a reduced carbon footprint, of substituting traditional road materials with plastic waste. Additionally, Baseena et al. (2023) discovered that the unique composition of materials integrated with plastic leads to noise reduction on roads.

Veropalumbo et al. (2023) approached the topic from an environmental perspective and highlighted the potential impact of diverting plastic waste from landfills to innovative uses.

This shift in waste management strategies would have significant implications. Yao et al. (2022) also emphasized the environmental and economic benefits of this approach. Their empirical research showed a significant decrease in production costs and greenhouse gas emissions, in line with global efforts towards eco-friendly practices and sustainable urban development. This economic perspective was also highlighted by Nouali et al. (2019), who identified significant cost savings, particularly relevant in developing areas.

Research Methods

This research employed an experimental method. It involved sourcing materials and sample preparation. Different types of plastic waste were collected in the northern part of Kazakhstan. When sorting the waste, it was noticed that they included plastics as polyethylene terephthalate, polypropylene, low-density polyethylene, and high-density polyethylene. At the initial stage, the maximum size of the plastic waste fell within the range between 50 and 200 mm. Since such dimensions are unacceptable in the preparation of road mixtures, they were cleaned and crushed to small spherical and triangular particles (about 4 mm). Then a homogeneous mix was prepared for the production of paving tiles with different plastic content (10, 15, 18, 22, 27 and 30%).

This was followed by conducted testing of samples. In the first stage of the study, samples with different plastic content were tested for compression strength with a load of 3000 kN at a rate of 18 kN/s. In the second stage, a Marshall stability test and a moisture content test were performed using a modified method. In the stability test, the load was applied to the specimen perpendicular to the specimen's axis. These characteristics are important for the materials used for road construction. Prior to moisture content test, the specimens were dried in a muffle oven at 110°C for 24 h in a water bath at 60°C.

In the next step, ab elasticity modulus test was performed to characterize the stiffness of the specimens. For this purpose, successive loads were applied, including a pressure-limiting deviator stress, i.e., applying a load changes the stiffness of the specimen. The elasticity modulus (MR) was calculated as the ratio of the applied deviator stress (σd) to the restored strain (εr). The LoadTrac-II device was also used for this purpose, which performs resilience modulus testing according to American Association of State Highway and Transportation Officials (AASHTO) standards. This device consists of linear actuator, pressure regulator, air filter, as well as compressed air source (≥500 kPa).

Results

Fig. 1 shows images of the sidewalk mix before and after mixing with plastic waste.

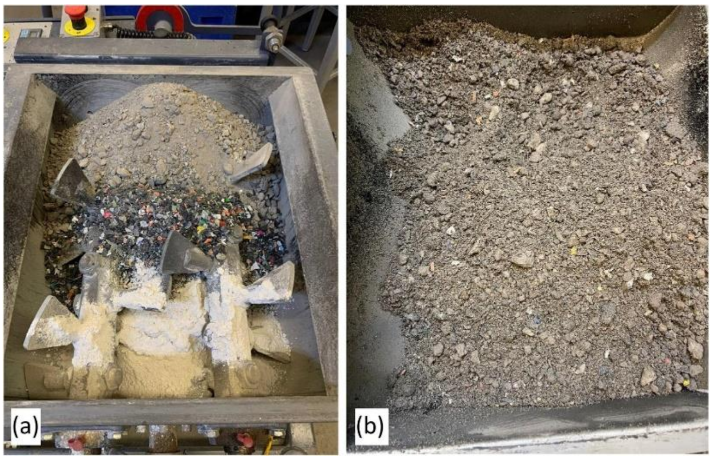

Fig. 1: Mixture before mixing (a) and after (b)
Source: Maghool et al., 2022.

In general, plastic polymers can be divided into several types:

- polyethylene terephthalate (PET, $(C_{10}H_8O_4)n$) – bottles, packaging tapes, films, sidewalk tiles, etc.;
- high density polyethylene (HDPE) – films, caps, bottles, etc.;
- polyvinyl chloride (PVC, $(C_2H_3Cl)n$) – tubes, films, bottles, also used in medicine;
- low density polyethylene (LDPE) – packaging films, cable insulation, cardboard coatings, etc.;
- polypropylene (PP, (C_3H_6) n – anticorrosive materials, fiber, medicine, hangers, etc.;
- polystyrene (C_8H_8) n – disposable tableware, packaging, toys, stationery, etc.;
- polycarbonate, nylon, acrylic, etc. – safety glasses, bottles, putty, sealants, etc.

In turn, plastic waste is divided into the following types:

- mixed plastic packaging;
- film/trash bags/packaging materials;
- non-disposable plastic products;
- items made of short-lived plastic (used repeatedly, but for a small amount of time);
- household leftovers with plastic contents.

The percentage of recycled materials in this research is expressed by the mixture weight, i.e., the percentage of recycled materials was converted from weight to volume of the mixture by converting the weight of recycled materials to volume using specific gravity. Then the volume percentage from the unit volume of the mixture was determined, with the remaining percentage coming from the primary materials (Santos *et al*., 2022; Santos *et al*., 2017). Samples without and with added plastic were tested for compressive strength, the results of which are shown in Fig. 2. For the specimen without plastic content, the strength value amounted to 3 N/mm^2. From the overall results obtained, it can be seen that the specimens containing plastic waste show better results. The strength increases with the increase of the percentage of plastic content. However, the value decreases at 30% plastic waste content. It can be concluded that a certain percentage of plastic content not only changes the number of binding materials saved, but also leads to an increase in compressive strength, which is the most important characteristic for road materials. This requires optimizing the amount of plastic added used for modification. Contents that are too high or too low may not contribute to the performance of the sidewalk mix. There is a possibility that higher concentrations lead to a separation of phases between the polymer and bitumen. This may be due to the binding properties of the polymer.

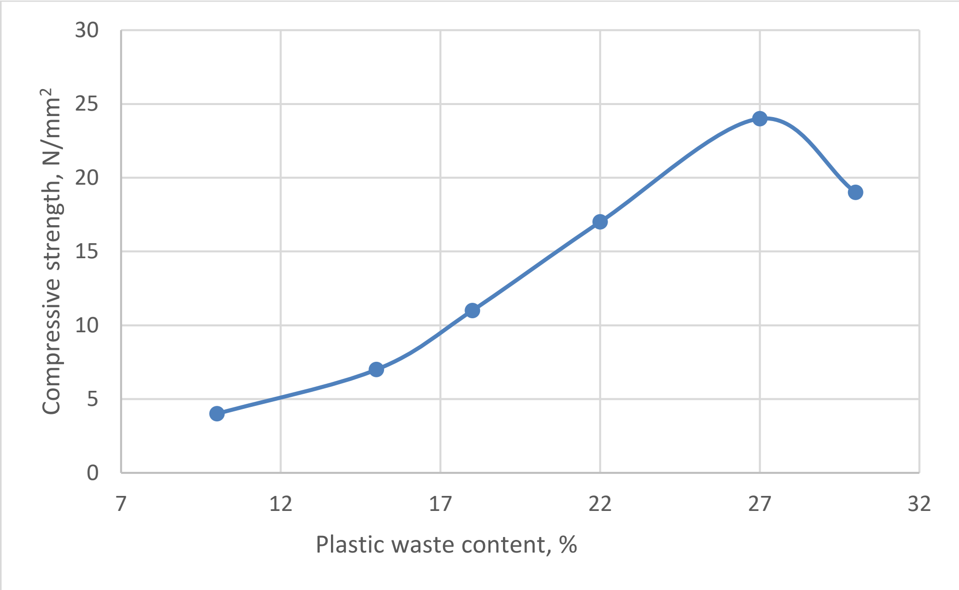

Fig. 2: Graph comparing compressive strength vs. percentage of plastic content

The Marshall stability test is primarily the same compression test, but the load is applied until the specimen collapses. This test is necessary to understand performance in further sidewalk development. For the test, the specimens were heat treated to 135 °C and pressed with compactors on both sides. The results obtained are summarized in Table 1. From the values, it is noticeable that the stability increases when the polyethylene content is high. For example, Ma *et al.* (2022) found out that an increase in the percentage of plastic significantly affects the elastic behavior of the modified binder. Khan *et al*. (2016) report that plastic increases the strength in road materials. Their reuse in asphalt leads to potential environmental and economic benefits. The addition of plastic waste plays a significant role in improving the elastic behavior to extend the service life of pavements in terms of reducing the susceptibility to rutting and cracking. In addition, the use of recycled waste will play a significant role in reducing the use of non-renewable resources, building sustainable pavements and reducing environmental impact while reducing waste dumped in landfills.

Table 1: Marshall stability test results

Plastic Waste Content, %	Marshall Stability, H
0	1100
10	1700
15	1800
18	2200
22	2500
27	2800
30	3700

Fig. 3 shows the results of the moisture content test. By analyzing the values obtained, it can be concluded that as the plastic waste content increases, the moisture content decreases. Incorporating plastic waste into paving tiles can improve moisture resistance and bonding properties as well as facilitate temperature performance without increasing costs.

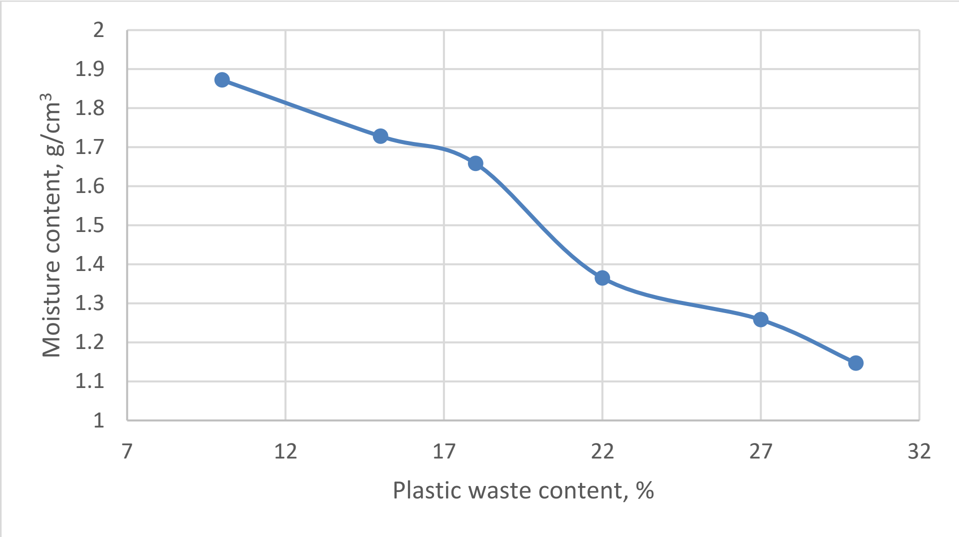

Fig. 3: Moisture content curve

Table 2 shows the results of measuring the elasticity modulus for the samples as a function of the plastic content percentage. The results also show that the elastic modulus increases with the percentage of plastic waste. However, just as in the compression test, the value decreases at 30%, confirming the influence of the plastic content percentage on pavement performance. However, it should be taken into account that elasticity modulus can be affected by such factors as the shape of the crushed plastic particles, the distribution of grain sizes, moisture content, etc. Given the relationship of the elasticity modulus to the long-term behavior of coarse-grained materials, the use of a correct estimate of the elasticity modulus affects the pavement design process and performance. That is, it is necessary to take the values of the elasticity modulus into account in order to correctly assess the pavement. In addition, it can be concluded that future studies require considering the difference between predicted and measured values as well as errors compared to the standard error limits in all proposed models.

Table 2: Results of measuring the elasticity modulus

Plastic Waste Content, %	Elasticity Modulus, M_R, 10^3 kPa
0	69
10	105
15	250
18	380
22	439
27	573
30	380

Thus, adding or replacing original materials with waste plastic will result in a permanent reduction in energy consumption as the ratio of plastic increases. It can also be concluded that the inclusion of plastic will significantly save water consumption. Water is used mainly in the production phase, where it also contributes to cost reduction. Carbon dioxide emissions, as well as energy consumption, follow the same pattern (Ma *et al*., 2022). That is, the addition of plastic waste can lead to a decrease in CO_2 emissions. This is primarily due to the replacement of original materials, the production of which requires a significant amount of energy and produces greenhouse gas emissions and air pollution. For example, Assaf and Abdo (2022) report that replacing 20% of original materials with plastic leads to a reduction in carbon dioxide emissions by almost half (from 13.4 million kg to 9.7 million kg). Energy consumption in the sampling process is mainly associated with the processes of plastic grinding, filtering and drying. Paving slabs made with the addition of plastic waste consume as little energy as possible while having the least negative impact on the environment and ensuring a long service life.

In general, the useful life of the road surface depends on the carrying capacity of its foundation. The strength characteristics of the pavement under the influence of the properties of materials are of paramount importance in the paving slab design. The load on the paving slabs is distributed by a dense graded non-bonded aggregate matrix that distributes the load over a large area of the ground. The performance and useful life of these non-bonded aggregate layers is attributed to various index properties such as gradation, maximum particle size, aggregate particle shape, surface texture, moisture content, etc. However, it should be noted that paving slabs are often modeled as a continuous layer with effective rigidity. This leads to breaks under stressful conditions. It is also noticeable that a tendency to neglect the mechanical behaviors is simplified, which can greatly impact performance.

In this research, the addition of polyethylene modifiers can reduce fracture and wear resistance. Polyethylene is a type of material that, at certain low temperature ranges, tends to become stiff and hard and tends to crystallize as solids below the melting point of asphalt. It should also be taken into account that LDPE has a density of 0.91 to 0.94 g/cm^3, while HDPE has more than 0.94 g/cm^3. The polyethylene particles continue to stay solid when the asphalt binder becomes soft at high pavement temperatures, which increases the resistance of the modified binder mixtures to destruction. In terms of structure, a certain amount of plastic can bond with the asphalt. The crystalline phase of polyethylene can serve as a high-strength filler during modification and allows the particles to remain intact during the final sample preparation. The addition of polyethylene can improve performance at high temperatures, fatigue resistance and moisture resistance, i.e., improve performance, because it enhances the physical properties of the paving mix. The addition of polymers creates an interconnected matrix of polymer molecules and paving mix molecules, the physical properties of which are enhanced by the long-chain combination of molecules. Compared to polyethylene, polypropylene is difficult to mix with asphalt due to its high melting point, and the addition of PP reduces the plasticity of the binders. Therefore, modified paving slabs will have a wide operating temperature range from high to low due to improved strength and flexibility.

Concrete is a stable and durable material used in the construction of sidewalks. However, it is subject to cracking under extreme loads or surrounding weather conditions. To prevent this, there is a tendency to add polymers that shrink at high temperatures and expand at low temperatures, which makes the concrete hard and resistant to cracking. Polymer modification in asphalt mixes reduces the amount of conventional asphalt binder, thereby improving stability and performance at low temperatures. It is also worth considering that when using plastic waste, it is necessary to be careful and ensure that the recycled material does not contain harmful components and will not have negative consequences in the future.

The waste must be homogeneous in composition and available in sufficient quantity to be used as a replacement for primary agents. From the results obtained, it can be understood that the use of polymers improves the properties of the mixture for paving slabs, i.e., there is an assumption that the addition of plastic waste to bitumen can improve its properties. After all, bitumen accounts to about 60% of the cost of asphalt mixtures, so reducing the bitumen content can lead to cost reduction. This will add value to the recycling of plastic waste as an environmentally friendly and cost-effective method. From an economic and efficiency point of view, it is important to consider the costs associated with all stages of the life cycle in assessing the sustainability of paving slabs.

The cost of creating sidewalks that incorporate recycled material includes expenses for processing waste, mining, acquiring and producing basic materials, as well as transporting materials, equipment, site cleanup, digging, and layering and compacting roads. Integrating plastic into paving slab construction helps to increase efficiency, reduce landfill waste, and eliminate the need for new polymers. This can potentially lead to substantial financial savings and environmental benefits in the long term.

Discussion

The road system is important for the development of the infrastructure and economy. In principle, paving slabs are used in many areas, from footpaths to highways, but such designs are suitable only for light loads. Sidewalks can provide a durable road surface that will benefit a range of vehicles and, most importantly, people. When designing a road laying, it is necessary to take into account the deformation and stress states in the structure. However, many design concepts fail to realistically capture the structural system, resulting in unsuitability. Paving slabs are made from concrete or stone slabs of various designs and are placed on a sandy layer. The base and sub-base layers are the main elements of paving slabs. These layers can serve as a working platform and provide mainly structural stability to the surface of the paving slabs. In general, existing sidewalks are not able to withstand heavy traffic loads, leading to premature failure and decommissioning. The binder mixture (bitumen) used in the construction of sidewalks is an oil base, which further proves that there is a dependence on natural resources, the price of which is increasing at a great speed (Zhalgasuly et al., 2019; Skalozubova et al., 2016).

The results show that adding polymers to the mixture for paving slabs enhances its qualities, which supports the notion that bitumen's properties can be enhanced by adding plastic waste. Since bitumen makes up over 60% of the price of asphalt mixtures, lowering the bitumen concentration might result in cost savings. This will increase the value of recycling plastic waste as a cost- and environmentally-conscious practice. Thus, it is necessary to look for alternatives, since bitumen is a product that is depleted every day, just like oil.

There are many algorithms that describe the assessment of the impact of decisions related to the choice of resources and processes. For example, this can be attributed to the life cycle assessment (LCA). This methodology determines the sustainability and priority of improving the road surface infrastructure. In order to conduct an LCA for paving slabs, a variety of tools are needed covering various life cycle processes. This methodology makes it possible to analyze the indicators of energy consumption, climate change, environmental pollution, etc. (Ryskaliyeva et al., 2019)

In general, the LCA analysis structure is divided into 4 stages: definition of the scoping goal, analysis of life cycle inventories, assessment of life cycle impacts and interpretation. Santos *et al.* (2022) presents a detailed review of the LCA methodology, which describes the main stages, elements and approaches to modeling. It is necessary to determine the flows of energy, materials, greenhouse gas emissions and the amount of plastic waste used for each process involved in the system. The study of pavements using the LCA technique by Santos *et al*. (2017) obtained the results of understanding the potential differences in the life cycle of pavements by using American and European asphalt pavement tools.

Paving slabs with a component of plastic waste will be the best solution for countries with a hot and humid climate, because such tiles are durable, environmentally friendly as well as have many other advantages. The use of plastic waste in asphalt mixes to solve the problem of waste disposal is becoming increasingly popular. The results of the research of Meyyappan *et al*. (2022) show that the use of plastic waste can reduce the content of bitumen. Chaturvedi and Singh (2021) show that plastic waste can be used in concrete mix. Hu *et al.* (2019) has reported that the use of recycled waste in transportation infrastructure still constitutes a significant part of the efforts made by transportation practitioners for the paving industry. Osouli *et al*. (2019) has investigated the strength characteristics of agents with plastic waste for use in the development of pavements, where they demonstrate that the addition of plastic leads to improved performance. Although the results of laboratory studies on the use of plastics in asphalt concrete materials are often encouraging, a closer examination of the literature reveals a paucity of documented studies that include commercial scale use of plastic waste.

According to this research, adding polyethylene modifiers can lessen the material's fracture and wear resistance. Below the melting point of asphalt, polyethylene is a substance that tends to crystallize as solids and becomes stiff and rigid at specific low temperature ranges. High pavement temperatures cause the asphalt binder to become softer, while the polyethylene particles continue to be solid, increasing the modified binder combinations' resistance to breakdown. The polyethylene crystalline phase permits the particles to stay intact throughout final sample preparation and can be used as a high-strength filler during modification. By enhancing the physical qualities of the asphalt mixture, polyethylene can also enhance performance at high temperatures, fatigue resistance, and moisture resistance. When polymers are added, paving mixture molecules and polymer molecules interact to form a matrix whose physical characteristics are enhanced by the long-chain combination of molecules. Polypropylene has a higher melting point than polyethylene, making it more challenging to mix with asphalt. Additionally, adding polypropylene lessens the binders' flexibility. Due to their increased strength and flexibility, upgraded pavement tiles will therefore be able to operate in a wide range of temperatures, from high to low.

Economic and Environmental Aspects

As mentioned, while assessing the sustainability of sidewalk tiles, it is crucial to take into account the costs associated with all stages of the life cycle in terms of economics and efficiency. The cost of recycling, raw material extraction, procurement, and production are all included in the price of making waste-filled sidewalks. Transportation of raw materials, equipment, site cleanup, excavation, building, compaction of pavement layers, etc. are additional expenditure associated with construction (Zhalgasuly et al., 2021). Thus, the use of plastic in the manufacture of pavement tiles can enhance performance, lower the amount of waste sent to landfills, and do away with the need for raw polymers, which could ultimately result in cost savings and environmental preservation.

In general, the bulk of the costs falls on equipment and labor. Nevertheless, it is possible to reduce the cost through the use of plastic waste, which can have an economic effect. Thus, in order to reduce costs, it is necessary to replace expensive original materials with cheap counterparts in the form of recycled materials. The cost in this case may increase due to the improved life cycle. the addition of recycled materials may also increase initial costs only in exchange for the improvement of the characteristics of the final material. Salehi et al. (2021) reported that the modification of bitumen with plastic increases the cost, but benefits from a long service life. The results also demonstrate that it is necessary to pay great attention to the use of plastic waste to increase the generation rate and negative environmental accumulations of waste landfills. The average cost of production and transportation of plastic modifiers is 2-5% higher compared to traditional asphalt mixtures. It is also worth considering that quantifying the economic and environmental impacts of evaluating the use of various plastics requires a life cycle assessment.

During the service life of sidewalks, a complex work is carried out to preserve the sidewalks. Throughout the use of paving slabs by the vehicles, both the characteristics and properties of the pavement surface change. Thus, the frequency of maintenance work can affect the economics of production. Hake *et al*. (2020) indicate that the costs are reduced by 5.18% when plastic waste is added to bitumen mixtures. Saharia and Singh (2022) has demonstrated that the physical properties of bitumen improve after the addition of plastic, namely, the strength parameters. The addition of plastic not only enhances the properties of the bitumen, but also improves the performance, thereby increasing the service life.

It should also be taken into account that the lack of information on the production of mixtures containing recycled materials usually leads to the consideration of assumptions and hypotheses in calculations, such as greater energy use. However, drawing reliable conclusions from the LCA results requires direct monitoring of the production and construction infrastructure. Existing environmental benefits can be achieved through the use of each recycled material.

However, during the research process, it was observed that the specific environmental impacts of each type of plastic were ignored. For example, the use of plastic waste for sidewalks can adversely affect human health and safety, because plastic modifiers have the ability to leach, which will lead to pollution of the entire surrounding area, as toxic fumes will be released. Bayazitova *et al*. (2016) has studied the reduction of the negative impact of landfills filled with municipal solid waste as well as the reduction of their number and the creation of prerequisites for the formation of an infrastructure for the processing of plastic bottles. Therefore, it is necessary to consider different impact categories depending on the potential environmental benefits in further research.

Conclusions

In this research, samples with different plastic waste content percentages (10, 15, 18, 22, 27 and 30%) were studied. The addition of a small amount of plastic waste to the paving slab mix results in an increase in compressive strength, which is a key characteristic for paving materials. This may be due to the binding properties of the polymer. The values of the Marshall stability test results show that the stability increases at high content of polyethylene waste. Incorporating waste plastics into paving slabs can improve moisture resistance and bonding properties, as well as facilitate thermal performance without increasing costs. The crystalline phase of polyethylene can serve as a high-strength filler during modification and allows the particles to remain intact during the final sample preparation. Thus, the use of plastic waste reduces energy consumption, water consumption, as well as reduces greenhouse gas emissions and air pollution. The amount of plastic content in the mix changes the amount of retained binder materials. However, it is noticeable that the compressive strength values deteriorated with a plastic content of 30%.

The use of plastic waste in the construction of paving slabs will lead mainly to a reduction in the number of landfills in the territory of Kazakhstan (Akmola region), i.e., it will save natural resources and territories and thereby improve the characteristics of paving slabs and other asphalt concrete roads. The addition of polyethylene modifiers can reduce fracture and wear resistance, as well as improve performance at high temperatures and moisture resistance.

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