Polymer materials from recycled plastic in road construction

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Abstract. The article presents the problem associated with polymeric waste. The solution is proposed for the use of recycled polymer in road construction. The existing constructions of road surfaces, their main advantages and disadvantages are considered. The problem of utilization of domestic and industrial wastes is disclosed. The directions of using the products of plastic and rubber waste processing in road construction and in the construction of buildings are presented. Reuse of plastic waste contributes to reducing the impact of human life on the environment and the development of resource–saving technologies in road construction and building construction. The construction of the plastic road module from recycled plastic is developed. Module is resistant to rain and combustibles (oils and electrolytes), temperature extremes (−40 to +80 °C), has a high coefficient of adhesion of tyres (on a dry surface of 0.7–0.8, wet 0.3–0.4). The internal cavity of the module to accommodate communications (gas, communication lines, electrical equipment) and hatches for infiltration.

Polymers are widely used in the manufacture of products for technical purposes; packaging, medical devices and household goods. Products from polymers at the end of use fall into landfills. The proportion of polymers in the composition of municipal solid waste is constantly increasing. In Russia, it is estimated, on average, at 5–8%. The main components of polymeric waste are: polyethylene – 34%; PET – 20%; laminated paper – 17%; PVC – 14%, polystyrene – 8%; polypropylene – 7%.

Polymer waste, like the polymers themselves, is divided into: thermoplastic – polymers that, when heated, acquire the properties of plasticity, flowability, this type includes polyethylene, polypropylene, and others; thermosets – polymers that under the action of temperature do not become viscous–plastic or fluid. Of greatest interest for reuse are thermoplastic polymers. One of the promising areas is the use of polymeric materials in road construction.

The actual problem is the recycling of garbage for the purpose of re–use of processed products. The solving of this problem will allow to create new enterprises and improving the environmental situation of the environment. Waste processing for profile production significantly saves the consumption of polymer raw materials and electricity, and also contributes to an increase in the output without additional investments in the purchase of raw materials. In some countries, up to 90% of domestic and industrial waste is processed [1, 2].

The growth of motorization stimulates the tendency to intensify the reconstruction of the road infrastructure and improvement of cities. This trend makes especially urgent the task of developing...
economical road surfaces that have high operational qualities, indicators of modern technical level that allow to conduct year-round construction. In this respect, the prefabricated road surfaces have high potentials [3].

Roads, depending on the type of coverage, are divided into permanent and temporary. The following basic constructions of temporary roads are distinguished [4]: a) unsurfaced road (roadbed); b) with a low-grade coating: from soils improved by additives; wood–ground cover; collapsible (tread road and solid) with a wooden covering; winter road; ice crossings; c) roads with a transition type coating: gravel and crushed stone; prefabricated with a coating of reinforced concrete slabs.

Unsurfaced roads without a covering (figure 1 a) consist of natural material (sand, clay, stony soil, turf, etc.). Coatings of the simplest or the lowest types are constructed from an equalized rocky or coarse clastic soil (figure 1b), from soils reinforced or improved with various skeletal additives (broken stone, gravel, etc.), local inactive substances (granulated blast furnace slag, fly ash) [5].

Wood–ground cover (figure 1c) is arranged in the form of a continuous flooring of logs 0.25–0.30 m in diameter, laid perpendicular to the direction of movement and topped with earth.

Figure 1. Coverings of temporary roads of the lowest type: a – unsurfaced roads (roadbed); b – covering from a rocky ground; c – wood–ground covering; d – covering from wooden boards; e – cover from collapsible road plates; f – snow cover; g – ice cover.

Roads with collapsible cover are used in swamps I and II types, on permafrost, fine–dispersed and heavily humid soils. The main element of the road are wooden boards (logs 6 m long, 0.18–0.25 m diameter fastened with tie rods) (picture 1 d), concrete slabs or collapsible road plates (figure 1 e). Winter road – roads with snow cover (figure 1 f), operated only in winter, at minus temperatures, snow is used as a building material. Ice crossings (figure 1 g) – frozen surface of the reservoir, connecting land areas, the period of operation from several weeks to several months. Broken stone is used as the main product in the construction of broken stone roads (figure 2a). Gravel coverings (figure 2 b) are similar to crushed stone, but differ in the material used for construction. Efficient and economical way of building roads withstandin high loads is the use of road plates (figure 2c, d).

Figure 2. Temporary roads with a transition type: a – broken stone; b – gravel cover; c – covering from ferro–concrete plates; d – covering from ferro–concrete plates with the subsequent tightening by cables.
Cured coatings (figure 3a) are arranged by the method of laying natural stone, pavers. Today they are rare and are used mainly in the construction of paths in parks. Prefabricated cement structures (figure 3b) are used in the construction of bridges. Asphalt coatings (figure 3c) are one of the main (service life is not less than 7 years). Concrete roads (figure 3d) are widely used abroad, in Russia this technology is not popular (it is used mainly at airfields), since asphalt laying is cheaper.

The types of road surfaces considered have both advantages and disadvantages. The main disadvantage is that during their construction, the use of natural materials are gravel, sand and bitumen obtained from such minerals as shale, coal, oil, which from year to year are depleted, becoming more expensive, which fast increases the cost of construction.

Group of companies «Ruscomposite» is engaged in the production of lightweight composite panels (figure 4a). Advantages of these construction is: ease of assembly; high resistance to loads (up to 80 tons); small weight of plates allows them to be transported with low economic costs. The possibility of application in areas with complex geological conditions (swampy terrain). Disadvantages: fragility as a result of repeated exposure to heavy equipment (especially crawler); restrictions on the speed of movement of transport.

In the road construction of foreign countries there is a tendency of resource saving. In the production of road surfaces, both new and materials obtained as a result of processing rubbish, which has real prospects for development.

As the amount of rubbish grows rapidly at any rate, even in the oceans there are whole islands of plastic rubbish. This fact leads to the idea of using rubbish to replace traditional materials in road construction with plastic processing products.

An example of adding polymer from recycled plastic to an asphalt mixture is the experience of KK Plastic Waste Management (India) (figure 4b) and the MacRebur project in the English county of
Cumbria. Plastic waste is recycled, enriched with stabilizers and mixed with bitumen, which allows replacing most of the crude oil, resulting in a high quality asphalt, road, waterproof coating that is more durable (10 times) and durable than traditional asphalt. The cost of its production is 60% cheaper, as plastic waste is used here.

The production of asphalt with the addition of plastic is 3% more expensive than usual, but its environmental friendliness and prospects completely compensate for increased production costs.

In Vancouver, a project is being implemented (until 2020) to create a road surface (figure 4c), which is 80% composed of asphalt and 20% recycled plastic. The main advantage is that several kilometers of it helps to clean the land of debris, also, its production requires a lower temperature in comparison with traditional asphalt, which significantly reduces energy costs.

In the composition of asphalt and plastic, there are the same hydrocarbons released from oil, so there is no difference in the level of toxicity between the materials. The plastic road costs 3% more expensive than the asphalt, which is justified by the savings in the disposal of huge plastic debris dumps.

Project Office VolkerWessels proposed the idea of building roads from plastic slabs (figure 4d). Advantages of these construction is: as the main material for their production is used recycled plastic; simplicity of the technology of laying / installation; resistant to the effects of precipitation and combustible substances (motor oils and electrolytes); resistance to temperature fluctuations (from –40 to +80 °C); the presence of a cavity inside the plates makes it possible to place communications (gas, water, communication lines, electricians); possibility to provide heating of the coating; high coefficient of traction of tires; the possibility to apply all the necessary road markings, and the disadvantages are: the installation of «joint—to—splice» plates without fixing with each other, the lack of data on the maximum weight that the plastic can withstand the service life, the ability to withstand the daily load, it is not clear how the plates behave when the water in the water channel freezes.

American technologists have introduced an alternative coating EcoRaster (figure 4e) made of plastic mixed with the traditional components of the usual road, waterproof canvas is a lattice plate connected in a single system. Cells of blocks are filled with pebbles, gravel or vegetation, which saves soil cover from erosion, and storm water is cleaned of pollution by natural filtration.

Advantages of this coating are: durability; simplicity of technology and short duration of repair, and consequently budget saving. In one year of EcoRaster coverage, the level of greenhouse gases decreased by 300 tons.

In the US state of Arizona apply asphalt coating – with the addition of rubber chips from recycled tires (figure 4f). The main component of asphalt, in addition to gravel and sand, is bitumen obtained from the processing of carbonaceous minerals (oil, coal, slates), with the implementation of reverse technology, the substitute for bitumen is obtained from old automobile tires.

Rubber crumb obtained from the processing of tires in a mixture with asphalt forms a stronger, «quiet», quick–drying after precipitation, and also less slippery in comparison with the asphalt coating. From one tire from a car get 2 kg. rubber crumbs. Such asphalt is already used in California, Arizona and Florida, the potential of this material is studied in Texas, Nebraska, South Carolina, New York and New Mexico, but only 12 million tires are used for processing, although 300 million tires are recycled annually in the USA, which as a rule are not processed. American experience has come in handy in Israel, where refined products are in short supply.

Bricks and even tiles are also made from recycled plastic. Platio (Hungary) builds solar energy generators (figure 5a) by applying solar collectors from tempered glass to molded shapes from recycled plastic. The pavement folds like Lego puzzles, and produces 160 watts of clean energy per square meter.

MiniWiz (Taiwan) has launched a project to manufacture paving slabs from plastic waste processing products (figure 5b). To create one tile, only five PET bottles are used.

Colombian architect Oscar Andres Mendez proposed to make plastic and rubber waste structures for the construction of temporary or permanent buildings (figure 5c). Construction of such structures is 30% cheaper than traditional structures. Plastic blocks are assembled as a lego simple attachment
system, which facilitates the construction of buildings. In the Chinese province of Shaanxi, an automobile high-speed road of 122 km was built from construction debris, using 6 million tons of waste to build a road cushion. Thus, approximately $47 million, 3.4 million m$^3$ of sand, 32 tons of coal, and, most importantly, 200 hectares of land that would have been required for the disposal of waste, were saved. About 47 tons of garbage per kilometer.

**Figure 5.** Building structures from recycled plastic: a – pavement generator of solar energy; b – paving slab of plastic debris; c – building structures from recycled plastic.

Based on the results of the analysis, it can be concluded that there are promising innovative directions for the use of recycled plastics in road construction in order to obtain a high-quality and durable coating. Based on the analysis, the construction of the plastic road has been developed (figure 6) [6, 7].

**Figure 6.** Construction of the plastic road module

As a basic material for its production of plastic road modules, it is planned to use plastic debris. Technical characteristics of the plastic road module: overall dimensions of WxLxH 2000x3000x250; operating load up to 25 ton; guaranteed life of 15 years.

Modular plastic road has the following advantages: resistance to sediment and combustible substances (automobile oils and electrolytes); simplicity of installation technology (several days); resistance to temperature fluctuations (from –40 to +80 °C); the presence of a cavity inside the module makes it possible to place communications (gas pipeline, communication lines, electric); it is possible to provide for heating of the coating; the ability to apply all the necessary road marking in the process of manufacturing the module, which significantly increases the resource markup; the reliable fixation of modules among themselves prevents both transverse and longitudinal displacements; modules can be recycled and applied in the manufacture of new constructions; low cost of raw materials (15 rubles. kg); high coefficient of adhesion of tires on a dry surface 0.7–0.8, on a wet 0.3–0.4. The benefits of using recycled plastic in road construction are double: both for the environment and for the economy due to the fact that the garbage (plastic bottles, glasses, bags) that needs to be recycled becomes a building material, i.e. useful raw materials. When the bitumen is replaced with plastic and in the manufacture of modules, the temperature of coating production will decrease from 160 °C to 120 °C, which contributes to energy saving, greenhouse gas emissions into the atmosphere are reduced, the lifetime of the coating will increase significantly. With the advent of cracks, repairs are made by heating and redistribution of plastic. The low weight of plastic road plates and the ease of their installation will significantly reduce the economic costs when transporting them. The use of technologies for the construction of road surfaces with the use of materials obtained during the processing of plastic waste will save considerable sums in the repair of roads. Almost one million kilometers of roads each year requires an investment of 1–2 trillion rubles. At present, the share of modified roads with the addition of polymers in Russia is 5% compared to 15% in the US and China and 20% in Europe.
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