

Cold pelletized asphalt concrete mixture from reclaimed asphalt

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Abstract. The authors of the article propose a technology for the sustainable reuse of old asphalt concrete granulate, the stockpiles of which increases annually by tens of thousands of tons. The article describes an approach that allowing to process the granulate of old asphalt concrete to make cold asphalt mix, equal in terms of strength and water resistance to hot asphalt mixes. Pelletizing old asphalt granulate concrete in a heated state leads to stratification of large agglomerates with the further building of granules from small particles of the material. These processes lead to a change in the initial dispersed composition of the old asphalt granulate, along with the structuration of the material. The resulting material is not subject to caking and can be stored for a few years in a cold state and does not require preheating when laying in the pavement. Its preliminary classification and fractionation are not required for the production of pelletized material based on the old asphalt granulate. After milling it can be immediately used for the preparation of a pelletized asphalt mix, which is crucial in terms of material reuse.

Keywords: reclaimed asphalt, pelletizing, cold asphalt concrete mixtures, asphalt concrete, mineral powder, bitumen

1 Introduction

Currently, engineers widely use asphalt granulate in various road construction works in the Russian Federation it is commonly called asphalt bits.

In the Russian Federation, aged asphalt concrete granulate is defined as a product obtained as a result of cold milling of asphalt concrete pavements or crushing of asphalt concrete scrap and subsequent screening.

The increased frequency of road bituminous layers resurfacing with new materials have led to a multiple increase in old asphalt concrete granulate production, which enables a wider and more efficient use of this material, not just as a component in traditional asphalt concrete mixtures, but as an independent material with old asphalt concrete granulate as raw material.

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The authors of the article propose a technology for the sustainable use of old asphalt concrete granulate, the volumes of which reach tens of thousands of tons per year in regional centers. At nearly every asphalt concrete plant one can see stockpiles of old asphalt granulate occupying the usable area and increasing in volume every year. The existing methods of its utilization cannot fully solve the problem of its accumulation, and therefore there is a need to analyze the causes of the current situation and develop approaches that contribute to solving this problem.

Old asphalt concrete granulate (hereinafter RAP - reclaimed asphalt pavement) is obtained during the road works by milling asphalt pavement upper layers, and, commonly, is returned and stored at the landfills and territories of the asphalt plant. At the same time, a question arises: why RAP, which originally is the material of the high-quality expensive road surface, cannot be used to obtain a new high-quality asphalt concrete pavement in full? It would seem that by heating old asphalt concrete granulate fractured due to traffic loads, it is possible to obtain a new material, equal in quality to the original asphalt concrete.

During the service life, the pavement material is exposed to traffic loads and natural factors such as temperature changes, humidity, solar radiation, etc. The influence of each of the listed factors on the fracturing process of the pavement material during service life is extremely difficult to assess, but their combined effect leads to the active aging of bitumen. The process of bitumen aging goes through four main stages: hardening of the structure, its stabilization, the beginning of degradation processes and fracturing [1].

Bitumen aging is a significant [2-3], but not the unique factor, preventing the use of RAP as a material for making new asphalt concrete pavement. In the process of obtaining the old asphalt concrete granulate, there is a change in the initial granulometric composition of the asphalt mix, associated with the impact of transport loads, the presence of dust and dirt and crushing the stone material of pavement by milling [4-7]. In addition, other effects may appear in the pavement material due to local service life conditions, leading to a change of properties of the old asphalt concrete granulate from the requirements of regulatory documents, which is very hard to assess. The abovementioned topics are disclosed in detail in the studies of Dr. A. Lupanov. [8-10].

Thus, the large-scale use of RAP as raw material for new asphalt concrete pavement involves a preliminary recycling of the material, called regeneration, in accordance with the requirements of the regulatory documents of the Russian Federation. During manufacturing, RAP is divided into fractions and sorted depending on the type of crushed stone, the type and quality of the binder, the age of the granulate and then receives a certificate of its material. From each batch, experts take several samples to analyze the homogeneity of the material. The binder is extracted and tested in the laboratory using an extractor and rotary evaporator. Particular attention is paid to minimizing RAP moisture by ensuring that it is stored under sheds. In Russia, the regulation on the use of RAP first appeared in 2016.

In countries where RAP is used, appropriate regulatory documentation is mandatory. For example, in Japan, the successful use of traditional asphalt mixes with high content of RAP is regulated by standards at three technological stages:

- RAP crushing and sorting, stocks provision;
- Drying and heating RAP prior to asphalt mix use;
- Application of specialized additives to restore the necessary properties of the aged binder in RAP.

The amount of RAP added as a supplement to a traditional asphalt mix is determined by the respective manufacturing organization. According to analytical data [11], the content of RAP in the mixture is: in Japan, 50%; in Germany, some asphalt plants can produce mixes with 100% RAP. China has enacted a mandatory re-use of RAP in mixes, which removed limits for the content of recycled asphalt concrete. As noted in [12], in the United States, RAP has been effectively used in hot asphalt mixes since the mid-1970s.

The technology of using granulate as part of an asphalt concrete mix requires significant costs for the production equipment modernization, retrofitting laboratory equipment, expanding laboratory space, training of employees and increasing their number, etc., which does not allow us to consider it cost-effective enough, as it seems at first glance. This technology is considered as a resource-saving and "green" (environmentally friendly) for processing secondary resources around the world. The strategic goal of developed countries is aimed at achieving 50–80% processing of secondary resources in the coming years [13]. In Japan, prepared RAP is stored indoors to minimize moisture content. Up to 69% of Japanese asphalt plants are equipped with a separate drum for drying and heating RAP (so-called parallel heat method [14]).

To sum up, we should note the problems associated with the use of old asphalt concrete granulate as a component for a traditional asphalt mix due to:

1. The need to adjust the composition of the main asphalt mix to which RAP additions are applied.
2. Certification of old asphalt granulate.
3. Additional lab research costs associated with testing the properties of each batch of RAP material. (this expenditure item involves the retrofitting of existing laboratories with equipment necessary for the study of granulate taken from different sections of the road pavement);
4. The need of indoor production areas for RAP storage on the asphalt plant territory.

Thus, the use of RAP as a component of a traditional asphalt mix is associated with challenges, overcoming of which is difficult for most asphalt concrete plants operating in the Russian Federation, and in some cases simply impossible. Accordingly, there is a need to develop new technological solutions that allow processing the granulate of old asphalt concrete or using a large part of it in order to obtain a high-quality road pavement.

One way to solve this problem could be coating heated particles of old asphalt granulate in mineral powder and bitumen. Coatings are applied using pelletizing method in accordance with the patent of the Russian Federation No. 2182136 dated May 10, 2002. This method makes it possible to make an order-structured granule shell from mineral powder particles bound by bituminous interlayers of minimum thickness which saves the binder and improves the performance properties of the material. Samples of asphalt concrete from such a mixture have characteristics that meet the requirements of the regulatory documents of the Russian Federation for hot mixes and the value of the water resistance coefficient exceeding one. According to the authors, these parameters largely determine the durability of the pavement.

The structuring of asphalt binder shells on RAP particles can affect the aging process of bitumen in the pavement. The process is determined by a combination of factors associated not only with the service conditions of the road surface, but also with internal processes due to changes in the structure of the material over time. Similar phenomena are observed during the hardening of concrete, and duralumin aging [15], and a number of other materials in which hardening occurs naturally without external influence. To study the mechanism of road pavement fracturing during service life, it is necessary to separate the internal causes of bitumen aging, which cannot be influenced, and external, associated with service conditions.

Obviously, such a procedure cannot be implemented when the road pavement is formed and is in service. However, the granular material obtained by the described method does not show a tendency to cake in a cooled state and is suitable for long-term storage with further use as needed. This made it possible to control the change in material properties over time.

2 Materials and Methods

Logistics and laboratory equipment for the preparation of a granulated mixture based on old asphalt concrete granulate included:

- Industrial poppet type pelletizer with a diameter of 1.2 meters, and capacity of up to 0.2 tons per day; four gas cylinders; two gas burners;
- Laboratory equipment: drying oven; muffle furnace; vacuum unit for testing the water resistance of asphalt concrete; a set of sieves; mixer; P-10 press for testing building materials; freezer; a set of molds for molding asphalt concrete samples; penetrometer LP; analytical balance; shaking table; specialized furniture and other equipment for the preparation and testing of asphalt concrete samples.

In accordance with the established technological parameters and operating modes in the course of previous theoretical studies, the technology for preparing a granulated composite mix included several operations. Manually, the granulate of the old asphalt concrete was loaded into the poppet type pelletizer through the opening. The poppet type pelletizer is heated to about 160 (±10) °C. Within 5-7 minutes, the granulate is heated to a temperature of 160 (±10) °C. When the temperature reaches 160 (±10) °C, the pelletizing process begins. Further, depending on the technological conditions, a fixed portion of the binder and then a portion of the mineral powder in pre-measured volumes on the scales are added manually. The application of dry powder occurs within 1-1.5 minutes. The cycle of alternating input of a binder and dry powder repeats from 3 to 5 times. The final step is the last addition of a binder. At the end of the pelletizing process the poppet pelletizer is brought to the unloading position and unloads the hot pelletized asphalt mix. Production of 1 batch with a volume of 20-25 kg of the mix takes 25 minutes on average. After unloading the mix it cooled to room temperature.

Tests of finished samples were carried out in accordance with the requirements of regulatory documents of the Russian Federation.

3 **Results**

In 2005, a batch of pelletized asphalt binder was obtained with the following composition: mineral powder MP-1 – 87%, bitumen 90/130 – 13%. The diameter of the material granules ranged from 2.8 mm to 3.2 mm. The granular material was stored in bags in a closed, unheated room, i.e. subjected to external temperature influences. At different points in time, samples of asphalt concrete were formed from a batch of granules and tested in accordance with the requirements of the regulatory documents of the Russian Federation, the results of which are given in Table 1.

Table 1. Test results by year

Test year	Compression strength at +20°C, MPa	Compression strength at +50°C, MPa	Water resistance coefficient
2005	9.00	3.10	1.03
2006	12.0	6.00	1.00
2012	12.20	6.10	1.00
2013	11.90	5.90	1.10
2022	12.00	6.00	1.05

Pelletizing heated old asphalt leads to the stratification of large agglomerates with the further formation of granules from small particles of the material. Obviously, these processes lead to a change in the initial RAP dispersed composition along with new material properties. Thus, a series of experimental studies were carried out, including the fractionation of unpelletized and pelletized materials using square meshed sieves... Figure 1 shows the results of a study of the fractional composition of the granulate of old asphalt concrete before and after pelletizing.

In the process of pelletizing RAP, granular material gains an ordered structure similar to the structure of the asphalt binder discussed above. The result of this process should be an increase in strength of the processed material. Figure 2 shows a comparison of compression strength at temperature of +200°C for asphalt concrete samples made from unpelletized and pelletized granules. The graph shows that palletization significantly increases the processed material strength.

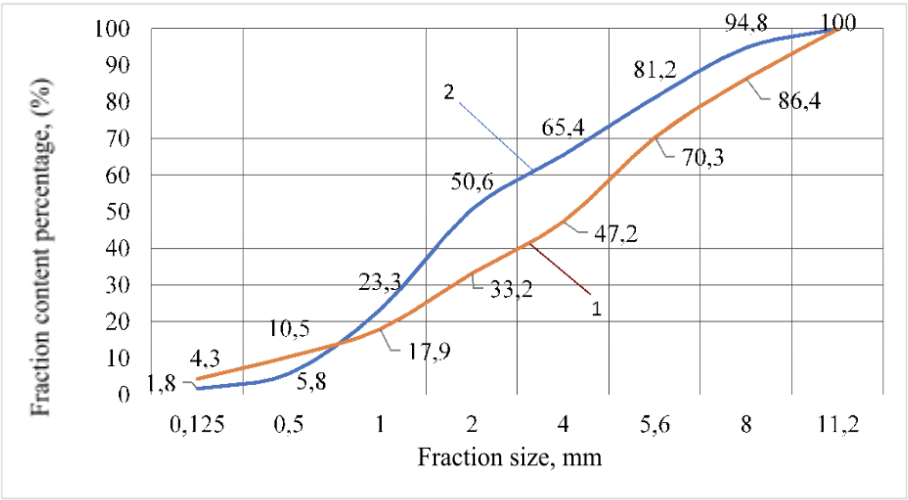


Figure 1. Change in the dispersed composition of the old asphalt granulate in the process of pelletization: 1 - unpelletized material; 2- pelletized material

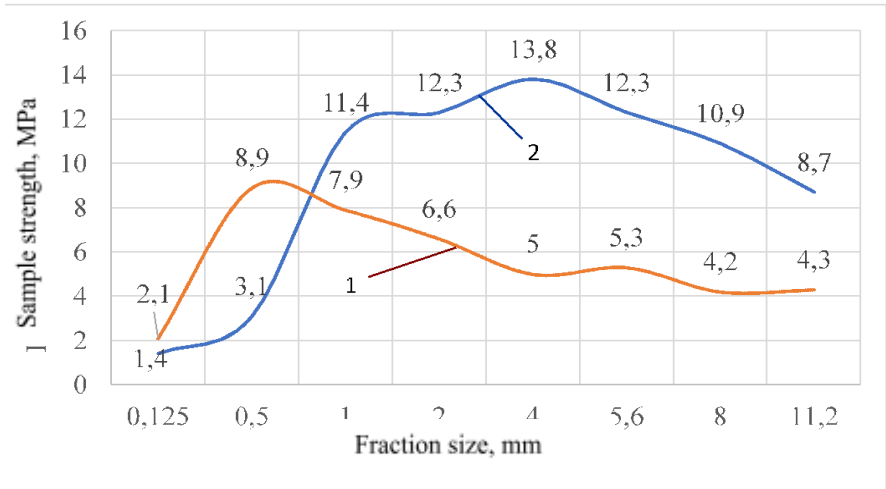


Figure 2. Compressive toughness at +200 C: 1 - unpelletized material; 2 - pelletized material.

Due to the identified technological features of the mix preparation, in the process of pelletizing old asphalt granulate mineral powder and bitumen were added with 20% of used motor oil, which is a production waste. Batches 1 and 5 used pelletized aged asphalt granulate without new components, batches 2-4 and 6-8 used pelletized aged asphalt granulate with the addition of mineral powder and bitumen with used oil, in various combinations. During the

tests, asphalt granulate fractions of 5-15 mm and 15-30 mm were used. The results of experimental studies are given in Table 2

Table 2. Test results of the pelletized aged asphalt granulate

Composition of batches, %				Characteristics							
№ of the batch	Old asphalt granulate	Mineral powder MP-1	Bitumen with used oil	Water saturation, %		Strength of dry samples, MPa		Strength of water-saturated samples, MPa		Strength after prolonged water saturation, MPa	
				before heating	after heating	before heating	after heating	before heating	after heating	before heating	after heating
Initial fraction of old asphalt granulate 5-15 mm											
1	100.00	0.00	0.00	2.60	3.20	4.60	3.90	3.60	3.80	3.40	3.40
2	91.00	8.22	0.78	3.10	2.40	4.10	3.50	3.30	3.20	3.50	3.40
3	83.30	15.39	1.31	2.00	1.70	4.40	3.70	3.40	4.00	3.80	4.10
4	77.00	21.35	1.65	3.70	3.50	3.80	3.50	3.00	3.30	3.60	4.50
Initial fraction of old asphalt granulate 15-30 mm											
5	100.00	0.00	0.00	-	-	-	-	-	-	-	-
6	90.00	9.60	0.40	4.80	4.10	2.30	4.10	2.60	2.60	2.50	2.20
7	80.00	18.30	1.70	3.00	3.10	3.50	4.00	3.10	3.30	2.30	3.70
8	70.00	27.10	2.90	3.00	3.10	3.50	4.00	3.10	3.30	2.30	3.70

4 Discussion

In accordance with the data given in Table 1, the strength properties of the material undergo significant changes over time, the nature of which in the framework of the experiment can only be caused by a change in the internal structure of the pelletized asphalt binder. This process corresponds with the first two stages: aging of bitumen – hardening of the structure and its stabilization. The subsequent stages of the asphalt concrete pavement failure - degradation and fracturing - may be due to the impact of traffic loads and climate on the pavement.

According to academician P. Rebinder, the ideal structure of asphalt concrete should consist of a fine fraction of the mineral part, the particles of which are bound by bitumen at its minimum content [16]. Individual large particles of the mineral part (in this case, gravel) can be considered elements of structural heterogeneity, as a result of which they absorb the stress in asphalt concrete. Therefore, the interface zones of the binder with the surface of crushed stone are the most vulnerable places in asphalt concrete. In addition, areas of the material in which

bitumen is in both a structured and volumetric condition can also be considered elements of heterogeneity.

During the service life of the roadway, the pavement material is exposed to repeated impulse impacts from the wheels of moving vehicles. Under these conditions, the main factor determining the durability of the pavement is the fatigue resistance of the material. Obviously, in this case, the most prone to failure are areas with structural inhomogeneities of the pavement material, in which defects are most likely to occur, leading to the degradation and fracturing of asphalt concrete.

The use of pelletizing technology for old asphalt concrete granulate makes it possible to obtain a fundamentally new cheap material suitable for creating a high-quality asphalt concrete pavement. The pelletizing process consists in processing the material placed in a rotating heated drum. As such the structuration of composite along with formation of minimum thickness binder shells between mineral particles occur, which provide a sharp increase in the strength of the formed granules. More details on material hardening during the pelletizing process can be found in [17].

Data analysis results revealed that one of the promising options is the use of pelletized granulate of old asphalt concrete as a material for cold asphalt mix. It was also noted that an important feature of the pelletized granulate of old asphalt concrete is resistance to caking during the storage of cold material, which allows for it to be stored for future use and used as needed. As follows from the data in Figure 2, the strength of the samples based on the old asphalt concrete granulate significantly exceeds the requirements of the regulatory documents of the Russian Federation. In this regard, there are problems with the densification of this mixture.

A certain method was proposed to solve this problem, according to which mineral powder and bitumen were added in the process of pelletizing old asphalt concrete granulate. This made it possible to change the structure of the material and obtain a qualitatively new material suitable for the efficient laying of road surface. A patent was received for inventing the method of producing asphalt concrete mix [18].

Table 2 shows the introduction of mineral powder and bitumen into the pelletized old asphalt granulate leads to a decrease in water saturation after heating the samples, which can be explained by the structurization of the material during pelletizing and, possibly, the addition of used oil into the bitumen. Heating dry samples reduces the strength of the pavement material, however, for water-saturated samples, there is a significant increase in strength after heating. This fact may be decisive when deciding on the use of the material.

Carrying out tests for batch 5 (initial granulate fraction - 15-30 mm) was not possible due to the fact that in the process of pelletizing the old asphalt granulate, the components of the mixture were restructured and excess bitumen was formed during its transition from the volumetric condition to the foil condition, which led to clumping and solidification of the mix during the cooling with the formation of a strong agglomerate. This is also clearly visible when comparing the results of batches 2 and 6, where the ratio of the components of the mineral powder is approximately the same and the amount of newly added bitumen for a larger granulate is almost two times less.

5 Conclusion

Study results analysis revealed a possibility to obtain a cold asphalt mix from the old asphalt granulate which is nearly equal in most characteristics to existing analogues at minimal cost of materials.

1. The developed pelletized asphalt mix, as shown by the results of experimental studies, is equal in terms of strength and water resistance to hot asphalt mixes in requirements of regulatory documents of the Russian Federation.

2. The strength of water-saturated samples in most cases exceeds the strength of dry samples, which achieves a water resistance coefficient of more than 1.
3. The pelletized asphalt mix is resistant to caking and it can be stored cold for a long time and does not require preheating before using it for laying the road surface.
4. The pelletized asphalt mix production technology makes it possible to sustainably reuse the granulate of old asphalt concrete to obtain high-quality material for paving with minimal consumption of mix components and reduce energy costs associated with heating the old asphalt granulate.
5. To produce pelletized material based on the old asphalt concrete granulate, its preliminary classification and fractionation are not required. After milling the granulate can be immediately used for pelletized asphalt mix, which is one of the key aspects of material reuse.

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