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INTEGRATED APPROACH TO USING TECHNOLOGY OF RECLAIMED ASPHALT PAVEMENT (RAP)

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Abstract

The article analyses the problems of lack the system approach to using reclaimed asphalt pavement technologies (RAP) in Russia. The purpose of this article is to review global experience with RAP, identify common issues of implementation of this technology and develop methods to ensure a comprehensive approach to the use of RAP in Russia.
The procedure of choosing a method of application RAP technology should addresses two main issues: cost-effectiveness and reducing the negative impact on the environment. Determining the most effective use of RAP technology is based on a combination of field and theoretical studies.

Peer-review under responsibility of the scientific committee of the International conference on Transportation Geotechnics and Geoecology

Keywords: RAP; asphalt pavement restoration technologies; asphalt recycling; cost-effectiveness.

1. Introduction

Worldwide the successful solution of the problems of proper roads maintaining is based on the joint efforts of government, business and scientists. Government is responsible for the up-to-date legal framework for using the best available technologies (BAT) in the road construction and restoration of asphalt pavement. Business structures are involved in investments and performing the works, and thus contribute to the practical application of new technologies. The scientific community is involved in the improvement of technologies and contribute to the innovative development of the road construction industry.

Development of new technologies was always focused on increasing cost-effectiveness, but recently along with the economic effects environmental issues have been considered, such as reducing the negative impact on the environment in the production of materials and execution of works.

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2. Rationale for reclaimed asphalt pavement technologies (RAP) development

According to the report «Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice» [1], more than 70% of the restoration of asphalt pavement cost is cost of materials. In this context, the relevance of reclaimed asphalt pavement (RAP) technologies is not in doubt.

If we look at the history of the use of secondary materials in the restoration of the road surface, it may be noted that some companies have begun to reuse materials such as tile, glass and rubber, in the early XX century, but it did not become widespread until the early 1970s, when the price of asphalt binder soared as a result of the oil embargo against the Arab countries. Manufacturers of asphalt have responded to this situation increased attention to the development of methods for recycling old asphalt pavement to lower volumes in the bitumen needs and, thus, were able to reduce the cost of the preparation of the asphalt mixture.

Many methods developed at that time, used to date, and have become part of today's traditionally used road construction technologies and rehabilitation of asphalt pavement.

The reasons for development of reclaimed asphalt pavement (RAP) can be divided into economic and environmental. The environmental effect includes:

- reducing emissions due to lower demand of oil and other natural materials production and transportation;
- transition from non-renewable to renewable resources;
- decreasing the territory of landfills for placing captured during repairs of old asphalt pavement.

The economic impact includes the reduction of the material cost proportion in the total cost of asphalt pavement rehabilitation, as well as reducing the costs associated with the transportation of materials to the work site.

Experts estimate the potential for reducing the cost of materials in the asphalt pavement restoration through the use of reclaimed materials (RAP) in the range from 3.4 to 6.8 USD per ton [3], depending on their proportion in the mixture (Table 1).

Table 1. The potential reduction in the cost of materials for the restoration of the asphalt pavement through the use of reclaimed materials (RAP)

The proportion of recycled material (RAP) in asphalt mixtures, %	Reducing the cost of materials used for the recovery of asphalt pavement, USD per ton
15	3,4
25	5,5
40	6,8

However, using reclaimed materials (RAP) to restore the asphalt pavement, should be guided by two main principles:

- mixture to restore the asphalt pavement, containing recycled materials (RAP), must meet the same requirements as a mixture consisting only of primary materials;
- specifications mixes for restoration of asphalt pavement, containing recycled materials (RAP), should not be worse than the technical characteristics of the mixture consisting only of primary materials.

3. Selection of the parameters of application of reclaimed asphalt pavement technologies (RAP)

In order to ensure that the technology of reclaimed asphalt pavement (RAP) meet the established criteria, it's necessary to choose the technology application parameters (Fig. 1).

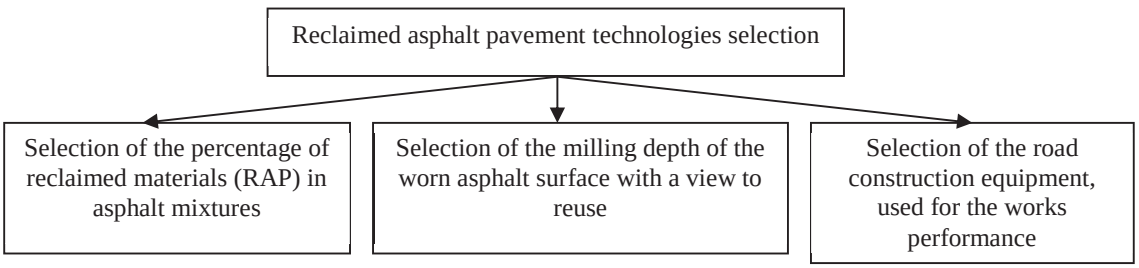

Figure 1. Selection of the parameters of application of reclaimed asphalt pavement (RAP) technologies

Selecting the percentage of reclaimed materials (RAP) in the mixture used to restore the asphalt pavement should be based on the comparison criteria for reducing the cost of asphalt mixture and to ensure durability and safety of the roadway operation. Selection of the milling depth of the worn asphalt surface with a view to its reuse in the asphalt mixture is determined by the condition of the roadway, and the need to restore the scale. Selection of road construction equipment used for the production of works must comply with the applicable set of technologies and available technical means.

Let's look in more details on the first parameter. In 2007, the US survey was conducted on the use of reclaimed asphalt pavement (RAP) materials in road construction. The survey showed that in most states the requirements of State Departments of Transportation are allow to use recycled materials for restoration of asphalt pavement, limiting their share at the level of 20-50%. Permissible levels of secondary materials (RAP) in road construction depend on the road category. The higher the load of the road, the lower limit content of recycled material (RAP) in the road surface. In practice, the average value of the percentage of reclaimed materials (RAP) in asphalt mixture used for the restoration of the road surface, according to expert estimates, is 12% [1]. The survey also showed the potential for increasing the percentage of recycled materials in road construction. For example, currently road construction companies in 20% of States use up to 29% of secondary materials (RAP) in the intermediate layer of the asphalt pavement, and in only 10% of States in the surface layer [1].

Next we consider the second parameter. Milling is an important part of the restoration of the road surface. Milling advantages are as follows:

- Removes worn layers of pavement;
- Provides the necessary clearance between the road surface and hanging over the road engineering structures (bridges, tunnels);
- Prevents the accumulation of masses of pavement over the maximum allowable on bridges;
- Helps to avoid comparing the roadway with curbs;
- Restores profile of the pavement, which is essential for its smoothness;
- Creates a rough texture on the surface of the roadway, which provides a good grip;
- Increases the efficiency of the process of removing the asphalt pavement and shortens the time of work performance.

Selecting the milling depth is an important decision in planning the restoration of the pavement. Often, the choice of the milling depth based on visual examination to determine the depth of cracks on the surface and the location of the weaker sections. The removal of these problematic or weak layers helps to reach long-term effectiveness of recovery of road surface.

Humidity and ambient temperature affect the operation of the crushing and screening device. When removed layer of asphalt pavement is wet or the temperature is too high, the resulting granulate becomes sticky and tends to accumulate in the feeders, crushers and screens. At such times, it's necessary to pay more attention to maintenance of the grinding units of recycled materials and feeder systems for the production of asphalt mixture. This situation can also affect the RAP gradation and asphalt contents.

Milling process must be carried out in compliance with environmental safety standards, that is necessary to ensure that removed asphalt surface does not pollute soil and water. The quality of grinding material, which can then be used a second time when you restore asphalt pavement must be tested for environmental safety. To test it suffices to take a small sample and investigate in the laboratory for RAP allowable pollution limits for using in asphalt mixtures. Crushed secondary materials should be tested for uniformity of texture. Uneven texture resulting worn or broken tip on the milling drum may cause problems associated with the presence of large particles. This can lead to a decrease in road safety in the use of retreaded asphalt for motorcycles. In accordance with the Methodology recommendations on restoration of asphalt concrete pavement of roads and foundations of cold regeneration methods issued by the Federal Road Agency "Rosavtodor", the content in asphalt granulate granules larger than 50 mm should not exceed 5% by weight [4]. Milled road surface should also be checked with respect to exceptions in cases where a thin, weakly bonded layers remain in place. If this occurs, the cutting depth should be adjusted to remove these layers. If we assume that these layers were in place, the effectiveness of pavement restoration will be greatly reduced.

Milling machines consume large amounts of energy as producing the removal of pavement layers by exposure to the pavement milling teeth mounted on the drum and rotating at a speed of about 200 revolutions per minute. In some cases, it may be advantageous to use special milling operations to remove certain sections of the road surface. Such operation may be useful when it is desired to grind the surface layer of the first pass of the milling machine, and the bottom layer in a second pass. Some contractors have recognized this type of milling operation to be effective, as it allows to achieve higher smoothness of the roadway and more uniformly apply the material to restore the asphalt pavement.

Next we consider the range of options the use of road-building equipment in asphalt pavement restoration. On the surface of the roadway, there are specific areas with sewers, drains, etc. In these areas there is a problem dispensing a small amount of the mixture. Using dump for these purposes, as a rule leads to the fact that the desired position falls on an excessive amount of material, and require attraction of extra labor and equipment for cleaning spilled material, which affects the whole process works. Special vehicle Shuttle Buggy SB-2500 [5] is designed for the storage and movement of the asphalt mixture of asphalt dump truck in order to ensure continuous stacking. Patented screws stirred material immediately prior to loading it into the paver that simplifies the recovery of asphalt pavement around manholes, close to curbs, allows placement of small volumes.

It turns out that even with the exact dosage the best technological option can not be achieved without the necessary quality of a device such as an asphalt loader. The experience of operating of asphalt loaders in the United States, Germany, Russia and other countries revealed that contactless and uniform loading of the paver allows these special vehicles to move not only continuously, but at a higher speed, since they no longer need to push the loaded dump or stop during their unloading. As a result, its practical performance is much closer to the theoretical.

4. Forming the base of the best available reclaimed asphalt pavement technologies (BAT)

Currently, in the Russian Federation in many sectors there is the development of national standards of the best existing technologies (BET). This process began in 2014, when they were issued orders of the Government of the Russian Federation №398-p "On Approval of the complex measures aimed at avoiding the use of outdated and inefficient technology" from March, 19, 2014 (as amended on August, 29, 2015) [6] and №2178-r "On the gradual creation of the chart of industrial directories of best available technologies in 2015 - 2017" from October, 31, 2014 [7]. These orders, as well as the Federal Law №219-FZ "On Amending the Federal Law "On Environmental Protection "and Certain Legislative Acts of the Russian Federation" dated July, 21, 2014 [8] increased environmental requirements applicable to Russian economic complex technologies.

By our opinion, the development of standards for best existing technologies is an extremely urgent task for the sphere of road construction in general, and for reclaimed asphalt pavement in particular. In this area are invested both public and private funds, so we can speak about economic efficiency, consisting of two components, such as commercial and budgetary efficiency. One of the main problems for Russian Environmental Policy in the medium term is to establish standards for the permissible impact on the environment on the basis of indicators of the best existing technologies (BET). Such a transition to the practice of developed countries, where the standards for the permissible impact on the environment for businesses is based on the regulations with reference to the registers best existing technologies (BET) fully meets the interests of the competitiveness of Russian enterprises.

It is possible to make a distinction between the terms "best existing technologies (BET)" and "best available technologies (BAT)". In the Russian Federation uses the term "best existing technologies", which are defined as technologies based on the latest science and technology, aimed at reducing the negative impact on the environment and have installed the practical application of the term, taking into account economic and social factors.

In the European Union in the late twentieth century, the concept of "best available technologies" was introduced to the business society. This term means the most effective and advanced stage in the development of production activities and methods of units operation, which indicate the practical suitability of particular technologies for creating a policy framework to ensure the limits for emissions, aimed at preventing and, if this is not possible, an overall reduction in emissions and reducing the impact on the environment as a whole.

Obviously, both terms have the sense of minimizing the negative influence of a particular technology on the environment. This is what is crucial. Only the same understanding of the target parameters of technical and technological standards between government controlling agencies and staff of polluters can lead to the desired results in time to reduce the negative impact on the environment.

5. The essence of the integrated approach to using the technologies of reclaimed asphalt pavement (RAP)

An integrated approach to using the technologies of reclaimed asphalt pavement (RAP) includes a number of action sequences on the justification for the decision making of contractor performing road construction work (Fig. 2).

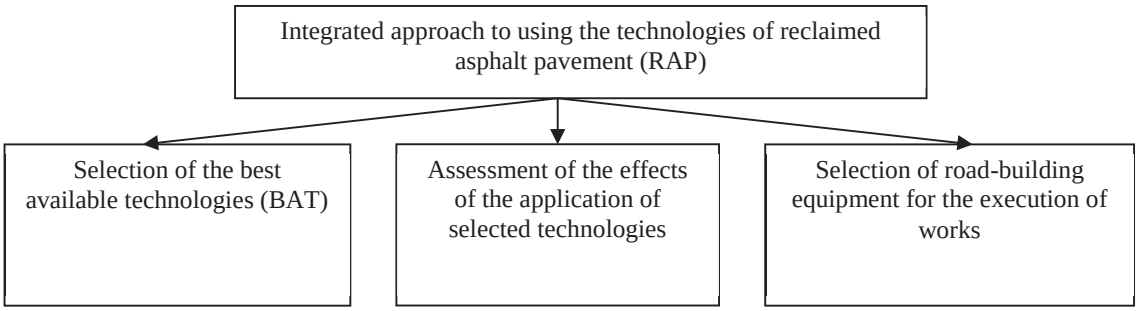

Figure 2. An integrated approach to using the technologies of reclaimed asphalt pavement (RAP)

The variety of existing in the world technologies is constantly updated with new ones with improved economic and environmental performance, such as reduced material consumption, reduced mileage specialized equipment. For example, at the beginning of the XXI century the technology of cold recycling has been actively used, allow contractors to reuse removed worn asphalt pavement after grinding. For this technology cold recycling machine was created, which is capable by its powerful cutting drum to crush pavement material (coating and substrate) to a depth of 30 cm, and in some cases even more, with a simultaneous processing it indicated binders (stabilizers), and the distribution of a uniform layer. The subsequent final compaction is performed by conventional rollers.

It should be noted that today should be clearly subdivided cold recycling on small depth (small or shallow recycling, up to 10 cm) and at a greater depth (deep recycling, up to 30 cm or more). This separation leads to the use of a specific set of several different machines, different types and amounts of binders, various expenses for performance of work (they are smaller in small recycling).

Generally cold recycling was originally conceived and developed as a variant of deep joint stabilization (strengthening) of the coating layers and the base asphalt emulsion with cement or lime additives. Under this option, the first respective machines was created that meet the original English term of cold recycling. Only later, in the process of accumulation of international experience, we can see more demand for an option of cold recycling on small depth. Taking into consideration financial issues, in the Russian Federation contractors mostly use the technology of shallow or small recycling coating layers (10 cm).

Despite its relative youth, geography and volume of the practical use of cold recycling gradually began to expand, especially after the appearance the special machines by companies Wirtgen, Bomag (Germany), Caterpillar (USA) and others. There is reason to believe that the peak of the popularity and success of production of cold recycling in Russia is yet to come.

The US produce almost 2 times more of the bituminous mixture than Russia and Europe, but use about 2 times less of the laying technique. The reason for this is adaptation of high-speed stacking technology, and there is no idle machines. Saving on handlers, Americans invented asphalt loader Shuttle Buggy, which ensures continuity of the process. In the 28 states in the US construction of roads without the use of such machines is prohibited by law.

The fact that the time of hot mixture transportation from the place of production to the point of laying depends on the asphalt plants (AP) location, and in urban areas, in addition, the intensity of vehicular traffic flows, the amount of congestion on the road dump motion. This leads to a cooling of the surface layer of hot asphalt at places its contact with air and truck body. When transporting heavy fractions asphalt mixture deposited on the bottom of the dump. Particularly acute this defect mixture during transportation rubble-mastic asphalt (PMA). In short, the transportation of asphalt mixture from asphalt plant to the point of laying leads to the formation of temperature and

fractional segregation (stratification) of hot mixture. Moreover, the temperature of segregation is not detected visually, it can be detected only with the thermal imager (infrared camera), but its consequences are no less, and perhaps even greater impact on the longevity of the pavement.

This mixture is compacted uniformly. "Cold spots" are not compressed enough, prone to increased moisture saturation and are characterized by a reduced strength. As a result, instead of the expected high-quality coating is formed rough road with low strength and durability.

When passing through the ambient temperature 0 degrees Celsius, such portions broken much faster than the bulk of the coating, because moisture in the coating becomes ice. The transition from the liquid to the solid state is accompanied by an increase in the volume occupied by and destroys the coating on the inside. When heavy traffic of vehicles, under the influence of stress on its wheels, quickly destroyed these areas. From potholes and cracks local coverage, significantly reducing the overall durability and often manifest themselves in 1-2 years of operation.

The evaluation process includes a comparison of selected technologies from the point of economic and environmental effects of their use with peers and best available technologies (Fig. 3).

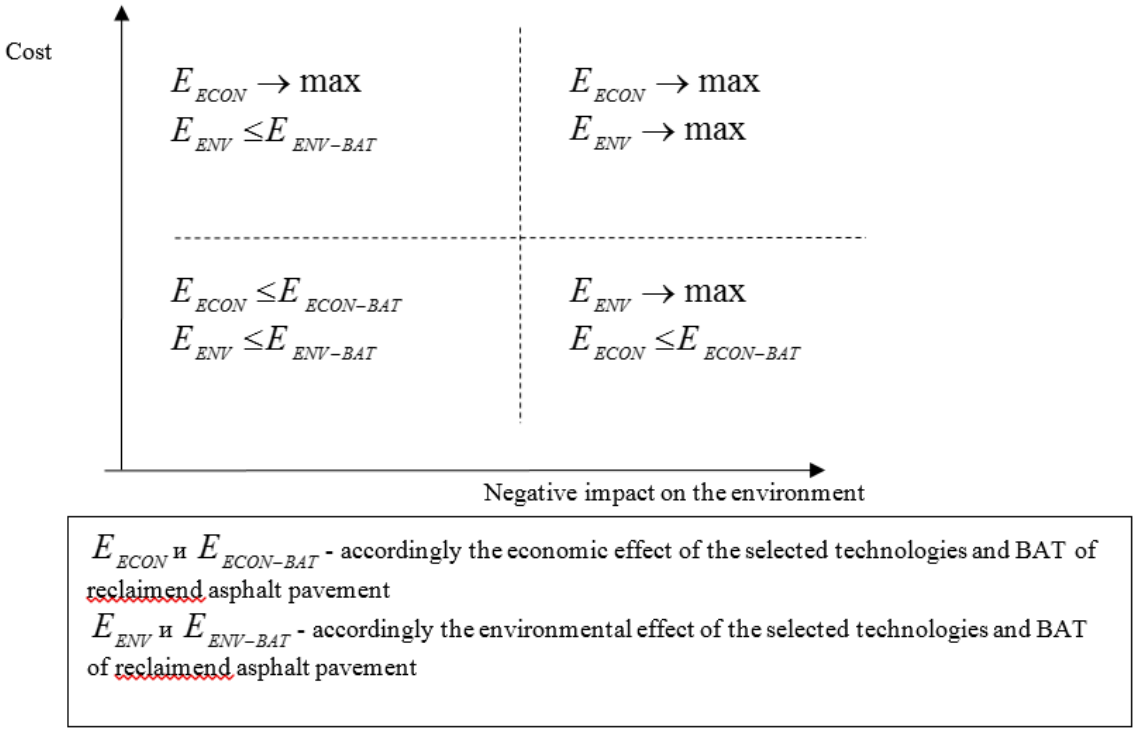

Figure 3. Evaluation of the technologies of reclaimed asphalt pavement (RAP)

In evaluation the technologies of reclaimed asphalt pavement (RAP) are several possible options. If the economic effect is higher than that of the best available technologies (BAT), its use is beneficial from the point of view of the contractor, but it is not beneficial from the point of view of society, as this technology has the potential harm to the environment. If the environmental impact is higher than that of the best available technologies (BAT), its use is beneficial, first of all, from the point of view of society. If technology can obtain an economic or environmental benefits greater than that of the best available technologies, such technology should be included in the BAT reference.

6. Conclusion

The survey showed, there is a large amount of the technologies of reclaimed asphalt pavement (RAP) in the world. Some technologies are based on using only virgin materials (both natural and synthetic), others have suggested involvement in the technological cycle of secondary materials. For more efficient recovery of road surface it is necessary to form an integrated approach to selection of technologies. Complexity involves technology choices by criteria to minimize costs and the negative impact on the environment and thus maximize the economic and environmental effects. Selecting the percentage of reclaimed materials (RAP) in the mixture used to restore the asphalt coating, based on the comparison criteria for reducing the cost of asphalt mixture and to ensure durability and safety of the roadway operation. Selecting the milling depth of the worn asphalt surface with a view to its reuse in the asphalt mixture is determined by the condition of the roadway, and the need to restore the scale. The choice of road construction equipment, used for the production of works must comply with the applicable set of technologies and technical means available. An integrated approach to the use of the technologies of reclaimed asphalt pavement (RAP) includes a number of action sequences on the justification of contractor's decision making performing road-building: the choice of the BAT, assess the implications of selected technologies and the choice of road-building equipment used for production work.

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