Monitoring Concrete Road Pavement Damages

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Abstract. The paper considers the main processes that affect the quality of concrete road surfaces. The quality of concrete pavement depends on the quality of the preparation of the base, the concrete components quality, and the quality of the coating technology. The processes of concrete components quality control, the process of its manufacture, as well as the control of road surfaces that have fully gained strength and are ready for use are studied. Examples of the defects formation on concrete surfaces are given. The factors influencing the occurrence of deformations in road surfaces are considered. In fact, concrete is a mixture of a binder, coarse and fine aggregate, various additives and water. The process of its production is a set of mandatory measures, without which it will not be possible to obtain high-quality durable material. The measures that exclude the defects formation on concrete road surfaces are proposed. The purpose of the paper is to analyze the processes of concrete road surfaces construction with the identification of the main measures to improve their quality

1. Introduction

In recent years a network of highways has been actively developing in Russia. The coating of some road sections is made of concrete or reinforced concrete. In the future an anti-noise layer can be laid on this coating.

Since it is possible to create almost any concrete shape and geometry, this material is considered a universal building material. Thanks to this high-quality material, modern architecture has made significant progress in the process of creating alternative forms in architecture and construction.

Concrete is a material with high compressive strength but low tensile strength. This leads to the need to strengthen the structure in the tension zones. Traditionally, this is done by using steel reinforcement in tensile zones.

The technology of the concrete pavements construction is somewhat more complicated than that of asphalt concrete. But, in spite of all the difficulties associated with preparatory work, selection of concrete composition, debugging of machines and mechanisms, concrete road surfaces have significant advantages. They are more durable (their service life is 15-30 years), more environmentally friendly (there are no bi-fog binders). Bitumen is produced from waste oil products which heavily pollute the earth. Concrete pavements do not form rutting, they are capable of carrying higher loads and are highly resistant to significant temperature changes. The most important advantage of concrete
pavements is their relative cheapness (one m² of concrete pavement is cheaper than asphalt concrete one).

2. Concrete pavement manufacturing process

The preparation of the foundation is one of the main processes in road construction.

First of all, when building a concrete road, it is necessary to check the quality of the soil of the road base since the foundation quality depends on how long the road will last without repair.

Before laying the concrete mix, the base preparation and the leveling layer, including the degree of their compaction with special density measuring devices (Figure 1) are checked. The flatness of the base and compliance with the design marks are also checked.

The next important process that needs to be monitored is the road surface reinforcement. Reinforcement can be made by separate rods and meshes. With a significant coating thickness reinforcement can be made by frames [1, 2, 3, 4].

The quality of the concrete mix depends on the incoming materials which are delivered to the ready-mix station (RMS). All inert materials used in the production of concrete coatings (large aggregates, sand) are subject to mandatory monitoring by of the RMS laboratory employees.

Initially, visual control of the received materials is carried out. In cases that raise doubts about the inert materials quality, their control is carried out by a construction laboratory. Special attention should be paid to the cement received by the RMS, namely, the storage conditions [5, 6, 7, 8].

In cases where cement is supplied in bags it is necessary to provide a dry room and storage of bags on pallets (Figure 2a), cement supplied by cement trucks (in bulk) is stored in special silos (Figure 2b).

The RMS operators together with laboratory assistants carry out a visual control of the mixture and, if necessary, adjust the dispensers [9, 10, 11]. For this, the dispensers are checked and adjusted daily. Such equipment control is carried out at least 1 time per month and is drawn up by acts (operability and serviceability of equipment). These measures ensure the quality of the concrete mix, since when the amount of components deviates from the norm, the strength of the concrete changes.

The concrete mix should be checked according to several criteria: uniformity, mobility, rigidity, the amount of entrained air involved. The amount of entrained air is checked both at the RMS and at the site of laying the concrete mixture in accordance with SP 78.13330.2012 [12] by a specialized device (Figure 3). The monitoring is made at least 1 time per shift and at least 1 time for every 200 m of coating [13, 14, 15].

The hardened concrete strength is checked by taking a coring from the concrete body (at least 3 cores are taken per 1 km of road surface) or by an ultrasonic method. Frost resistance is checked in
accordance with the instructions of GOST 10060.3-95 [16] by the dilatometric method. At the same time, water-saturated cube samples (100x100x100 mm) and cores ø100x100 mm, ø70x70 mm (GOST 28570) are frozen once, and the concrete frost resistance meter BETON-FROST is used (Figure 4).

Production of high-quality concrete mix, compliance and control of all processes, (from the receipt of materials at the RMS to the laying of concrete mix in the coating) are just a part of the measures that will make a high-quality and durable coating [17, 18, 19].

There are a number of other measures that affect the quality of the concrete mix. One of these measures is the care of the laid concrete mix. At the same time, it is necessary to take into account the ambient temperature [20, 21, 22].

At subzero temperatures, it is necessary to cover the concrete to create internal heat by the concrete body itself, or to produce electric heating of the laid concrete mixture (Figure 5).

Concrete maintenance is an important process that affects the finished coating quality [23, 24, 25]. At high outdoor temperatures, special compositions are used for treating the concrete surface (for example, film-forming compositions) which do not allow the moisture in the body of the freshly laid concrete mixture to evaporate. It excludes the appearance of temperature-shrinkage cracks in the finished coating (Figure 6).

The final process of the finished coating approval shows how correctly all the previous processes were performed. Non-compliance with the production technology, preparation of the bases, non-compliance with the set of measures for the care of concrete leads to the appearance of various kinds of defects formed on the laid concrete mix.
Such defects can be: surface waviness, coating rupture over the entire width, breaks in the middle and along the edges, heterogeneity of the coating texture, poor quality longitudinal and transverse joints, longitudinal and transverse cracks, insufficient compaction of the mixture (voids).

Factors affecting the appearance of defects: temperature insufficiency of the concrete mixture, excessive moisture saturation, non-compliance of the actual composition with the recipe, incorrect base preparation, defective overlap in the area of joints [26, 27, 28].

Technical problems are associated with the debugging and operation of machines and mechanisms: downtime of the concrete paver due to the delay of dump trucks, emptying of the receiving hopper when changing dump trucks, movement of the paver at high speed, vibrators at low frequency, incorrect installation of longitudinal slope sensors, incorrectly set screed plate [29, 30, 31].

Making expansion joints is important in the concrete road construction. The joints divide the concrete pavement into squares. They allow the squares to move horizontally and vertically at different temperatures. The same joints separate the different areas of the pour.

To eliminate defects and improve the pavement quality, taking into account that the roads experience shock, cyclic, and sometimes alternating loads, it is possible to recommend dispersed concrete reinforcement to improve the resistance to such loads [32, 33].

According to experimental tests, which are presented in these works, the use of dispersed metal fibers as reinforcing materials can improve the properties of concrete in road pavements. In this case, the bending strength, resistance to alternating loads, impact resistance and, in general, the technical characteristics of the road surface exceed those for similar reinforced concrete surfaces.

In flexural testing, structural performance is improved due to the effect of the fiber on energy absorption and flexural properties. The results clearly show that the use of metal fibers can increase fracture toughness and improve behavior after cracking when the design load is large enough. In the same way, steel fibers increase ductility and energy absorption of reinforced concrete elements subjected to alternating bending by static or dynamic load (Fig. 7, 8).

![Figure 7. Reinforced concrete structure vibration graph.](image)

![Figure 8. Graph of the vibration process of fiber concrete structures.](image)
Steel fibers can partially and sometimes completely replace conventional bar reinforcement due to the fact that steel fibers also increase the load-bearing capacity of structures [34, 35].

Steel fibers that are randomly distributed in the concrete mix can have different volume fractions, geometric shapes, and orientations. In general, the advantage of using a concrete coating is environmental friendliness and better behavior at high temperatures compared to asphalt concrete.

At the same time, it is necessary to observe safety measures when working with the bulk components of the concrete mixture.

It can be seen from the graphs that fiber-reinforced concrete elements perceive large loads and have less deflections than reinforced concrete ones. Oscillations decay faster. The structure itself is capable of taking the load. All this shows that the use of dispersed reinforcement in road structures that perceive similar loads improves the operational properties of such structures[36, 37, 38].

When choosing the parameters of fiber-reinforced concrete, it is important to adhere to the technology of preparing the fiber-concrete mixture while ensuring the uniformity of the fibers distribution in concrete. The main geometric parameter of fibers is the length to diameter ratio. The percentage of the fibers content in the composition and, accordingly, the strength and deformation characteristics of fiber-reinforced concrete depend on this parameter. The workability of the fiber-reinforced concrete mixture and, accordingly, the method of laying and compaction depends on the same parameter. Recently, more and more fiber-reinforced concrete is used with a plasticizer.

3. Conclusion
In the course of the analysis of the processes of concrete road surfaces construction, the main measures to improve their quality were identified.

The concrete coating quality is determined at each stage of the construction process. In particular, they are the base quality, the reinforcement and concrete mix quality, the quality of the work on the coating device, including concrete care and electric heating at negative temperatures.

It is shown that the use of dispersed reinforcement will improve the quality of the finished coating and its performance.

Undoubtedly, today concrete roads are superior to asphalt concrete in many respects, which makes their use relevant when it is necessary to improve the quality of roads.

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