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System approach of organization methods and ways of road construction mobilization of permanent and temporary roads at construction sites

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Abstract: Today, the issue of a qualitative approach to the design and construction of temporary roads at a construction site is particularly important for the organization of construction. For the construction of temporary roads and their effective functioning, it is very important to achieve high performance characteristics of the road surface. The article discusses the road surface Imprint – a new technological solution for the construction of temporary roads. Objective: The purpose of the study is to determine the possibility of using this coating as a coating for temporary and permanent roads. Results: The results of the study showed that Imprint coatings can be successfully applied where there is heavy traffic. Conclusion: The schedule of work is one of the main documents of the programme of work. It reflects the decision on the organization of work, the chosen organization method and the way of its mobilization, the sequence of technological processes, the arrangement of equipment and workers in private flows, contains other production and technical information. Imprint road surfaces have sufficient strength, have good abrasion resistance, impact strength, does not slip under the wheels of cars and pedestrians' feet, is resistant to the formation of ruts, resists aggressive environments well, has improved hygienic indicators. It is recommended to use Imprint road surfaces on a construction site.

Keywords: *Construction industry, Organization and management, Construction site, Road engineering, Road surfaces, Temporary roads, Economic evaluation.*

1. Introduction

Nowadays, the issue of temporary and permanent roads on the construction site is particularly important for the organization of construction. The properly organized process of supplying construction with all the necessary materials depends not only on the duration, but also on the quality indicators of the building structures being erected. Temporary roads can be different and arranged from different coatings, ultimately the reliability and efficiency of the functioning of this element of the construction organization system depends very much on the quality and performance of road surfaces. Therefore, research related to obtaining new materials that meet these requirements is very important. To solve this problem, it is especially important to study the characteristics of newly developed materials and determine the effectiveness of their use as a coating for permanent and temporary roads.

Imprint® A unique hot-use material developed and manufactured by Prismo Limited, intended mainly for use as road surfaces. Imprint is a polymer-modified synthetic bitumen base; reinforced with metal and glass fiber with inclusions of sorted rubber and granite aggregates.

Imprint performs the functions of a decorative wear-resistant road surface. In the presence of 12 standard colors, you can choose almost any color scheme at will. Imprint is a full-color material, so its color does not change when the surface is worn. With the help of specially designed molds, after coating, it can be given the appearance of brickwork, cobblestones, tiles, granite, etc.
The study also aims to highlight the theoretical basis relevant to the field of research.

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Studies have shown that in-site transportation in modern construction in 70% of cases is carried out by means of vehicles on temporary roads and roads arranged for the permanent functioning of the building (Kazaryan, 2018a; Kazaryan, 2018b).

The quality of the road surface can be successfully investigated using bicycles and electronic scooters (Cafiso et al., 2022). The proposed methods of road surface survey include dynamic measurements (Shtayat et al., 2021). Road surfaces can also be used to generate energy (Mona et al., 2021). High humidity conditions cause significant damage to road surfaces (Rokitowski et al., 2021). The study of road surfaces is often carried out with the help of various vehicles belonging to end users (Staniek, 2021). The quality of road surfaces and the costs of their operation are significantly affected by climate change (Qiao et al., 2022). The joint behavior of the "coating - vehicle" system depends on the evenness of the road surface (Ma et al., 2022).

The development of temporary road coverings for construction sites is relevant not only for the central regions, but also for the Arctic regions (Demyanushko et al., 2021). Successive stages of deterioration of road surfaces affecting their operation are described in (Mehdi et al., 2022). The condition of the road surface can also be investigated on the basis of sound characteristics (Del Pizzo et al., 2021). When designing temporary roads, it is important to correctly determine their thickness (Tohidi et al., 2022). When determining the wear of road surfaces, it is necessary to determine not only the degree of wear of the coating, but also the direction of such wear (Yang et al., 2022). Incorrect design and consideration of road surface loads can lead to accidents (Alhaji et al., 2022). In a market economy, profit is of particular importance. It is a source of self-financing of the economic and social development of an enterprise. Profit is one of the summarizing indicators characterizing production efficiency. It reflects the final financial result of production and economic activity of an enterprise. Profitability characterizes the final financial result and the efficiency of production and economic activity. These main economic indicators largely depend on the organization of the highway construction work (proper arrangement of equipment and labour resources, the degree of use of fixed production assets, and the coordinated work of production units in the production process). These issues are solved in the process of production planning and management. In this case, an important role is played by the choice of the organization method and the way of work mobilization.

The issue of research, therefore, is to determine the characteristics of the analyzed coating and the possibility of its operation for permanent and temporary roads, in particular, this can be determined using the following tests: determination of material hardness, resistance to track formation, determination of residues during combustion, determination of cone precipitation, compression tests, high temperature tests, color testing, determination of slip resistance.

2. Materials and Method

Two methods are used to determine the degree of hardness of the Imprint material: the British BS5284 Method and the French NF T6602 Method.

Although the same instrument is used for both tests, the test conditions are different.

All materials are tested after two hours of heating at 200 °C.

The result of the test is the dent depth (dmm) recorded at the end of the test time. The results are entered into the specification using the French Method.

It should be noted that the results will vary depending on the heating time and temperature. It is very important to adhere to the accepted method.

2.1. Rutting resistance.

Samples are sent to well-known independent laboratories, where they are tested for rutting resistance - DD 184: 1990, now BS598 item 11o. Specifications are usually developed for asphalt pavements, however, the satisfaction of Imprint with these requirements is considered acceptable. The results are formatted as the depth (mm) and the rut rate (mm/h). The tests are carried out at two temperatures. The 45°C test is recommended for the UK, while the 60°C test is considered acceptable for hot climates and areas with increased load (i.e. more severe operating conditions). After the revision

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of the specifications, tests at a temperature of 60 °C may also be required in the UK. Their use is recommended in areas with very heavy loads.

2.2. Residues During Combustion

10 grams of the sample is placed in a muffle furnace for 1½ hours at a temperature of 750 °C. The initial weight is recorded with an accuracy of 4 decimal places, after which the weight after combustion is subtracted from it. The weight of combustion losses calculated in this way is divided by the initial weight and the volume of the binder is obtained.

Initial weight - Weight after combustion = Loss

Loss / Initial weight = Volume of binder

Initial weight - Binder = Combustion residue

For testing, it is important to take no more than 10 grams of the sample, since with a larger amount, smoke and soot form in the furnace.

Due to the nature of the material, it is necessary to record the results of three tests.

2.3. Cone Slump.

The cone is made by pouring the material into a funnel wrapped with silicone paper. The material is poured at a temperature of 200 °C. Before measuring the height of the cone, it is kept for 24 hours at room temperature. Then the cone is placed for 5 hours in an oven at a temperature of 90 °C, after which its height is measured again.

Initial height - Height after heating = Losses

Loss / Initial height = % of cone slump

This test shows a spread of polymer and sedimentary properties of the material, therefore, references to the maximum and minimum values are made in the specification.

Compression test at 25°C, 45°C and 60 °C.

The material is poured at 200 °C into a round formwork with a diameter of 55 mm and a width of 22 mm. After cooling, the formwork is removed. The material is then compressed by 11 mm using a Lloyd's Tensometer. The maximum compression is fixed.

Samples are made and tested in triplicate at room temperature, 45 °C, 60 °C.

The compression test can also be used as an indicator of reducing properties. Brittle materials can also be detected if they break during compression. Materials that do not break during deformation have better properties at low temperature.

Compression testing can identify instances with uneven filler distribution.

The results of this test depend on temperature, so it must be carried out in a temperature-controlled laboratory.

2.4. Testing With a Plate

Silicone rubber formwork is placed around the plywood panel. A rectangle of 100 mm * 40 mm is formed in the center of the panel, where the material is placed. Then the formwork is removed from the panel, and the block of material is left for 24 hours at room temperature. Then silicone paper is placed on the material, and a block weighing 2600 grams is placed on top. All this is placed in the oven for 5 hours at 90 °C, after which the expansion of the material is measured. The initial block and the block after heating are measured at the moment of maximum expansion. The result is entered as a percentage expansion of the original size.

This test is used to test the properties of the material for high temperature loads.

2.5. Color.

Color testing is performed twice during the Imprint production process. Before the start of the technological process, samples are taken from the beginning, middle and end of the batch and are usually checked for uniformity. The Lab color scale is used when making the test results:

L = Brightness;

+a = red;

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-a =green;
-b = blue;
+b= yellow.

After the technological process, when the material has cooled and hardened, the bags from the beginning, middle and end of the batch are examined. At this stage, you can visually assess all the differences in the batch.

Color specifications are given for samples used on the construction site; the heating conditions in the kocher may affect the results obtained.

2.6. Slip Resistance

Slip resistance is measured using a portable pendulum device. This procedure is carried out in accordance with TRRL Road Note 27 (Road Directions 27 of the Transport Research Laboratory).

The method of work organization can be considered as an activity for the alignment of all elements of a particular object, system in time and space. In this sense, the organization of road construction work involves the arrangement of equipment and workers at construction sites and their use in the course of work.

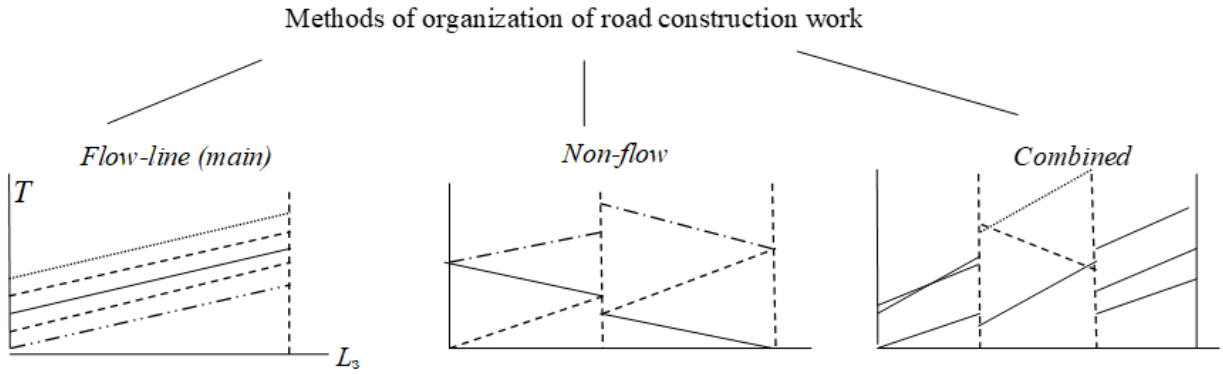

Figure 1.

The main ideas of the flow-line method:

- After the completion of work by the last unit, finished products are issued continuously and rhythmically at certain intervals (as a rule, every shift);
- Works are performed by specialized units (private flows);
- Each specialized unit is assigned to its own area (work zone);
- Flows may have a different pace of work, so the pace must be coordinated;
- The aggregate of private flows forms a complex flow.

3. Results

As a result of the conducted research and tests, it can be stated that the resulting material has the following characteristics that meet the requirements established for temporary and permanent road coverings.

Imprint coatings are intended for outdoor use as road surfaces in places where traffic is organized: on city streets, bicycle paths, lanes for public transport, intersections, roundabouts, vehicle parking lots, etc. Imprint can be used to mark elevated sections of the road in places where it is necessary to reduce the speed of vehicles: near pedestrian crossings, in front of traffic lights or intersections, on sections of roads with speed limits, for speed bumps, etc.

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lmprint is also used as a coating for pedestrian zones: on pedestrian paths along roads, sidewalks on bridges and roads, as coatings for large pedestrian zones or streets, in city squares, in areas adjacent to cafes, bars, restaurants, offices, administrative buildings, etc.

The Imprint coating does not slip under the wheels of vehicles and pedestrians' feet, is fireproof, resistant to chemically aggressive environments, while the coating is easy to clean, has excellent mechanical properties such as elasticity and resistance to abrasion and impact caused by heavy traffic.

Imprint coatings can be applied to almost any surface, such as new or old concrete, asphalt, wood or metal, without significant preparation, i.e. there is no need to remove the old coating, treat the surface with primers, arrange an additional leveling layer. The only exception is the surface of the paving stones, which is not recommended to apply the Imprint directly because of the weak adhesion with the coating. When applying the coating, the surface must be dry and clean, therefore, before applying the Imprint, it is recommended to clean and warm the surface with special gas burners.

One of the main advantages of Imprint is the rapid polymerization of the material; the coating can be used 45 minutes after application. Thanks to this unique property, Imprint is ideal for use in busy places where it is difficult or impossible to block the area used for coating even for a few hours: roads, bridges, pedestrian crossings, playgrounds near cafes, restaurants, offices.

Imprint coatings are represented by compositions with a layer thickness from 10 to 25 mm, depending on the operating conditions. The available range of Imprint products includes the following twelve basic colors: red, pink, ochre, burgundy, light gray, dark gray, brown, green, yellow-brown, stone, yellow, light yellow.

Any other colors are possible on request.

There are two types of Imprint for all the declared colors: standard Imprint C and Imprint C for increased loads.

The standard Imprint C is suitable for use on the roadway and pedestrian zones in the absence of specific requirements for rutting resistance. This grade has been tested for rutting resistance at 45 °C. It is more suitable for a temperate climate.

Imprint road surfaces meet the requirements for strength, abrasion resistance and impact resistance, resistance to rutting and sliding, chemical resistance and hygiene.

The Imprint tests were carried out by the Transport Research Laboratory in accordance with British Standards and the Manual for the Operation of Bridges and Roads (NDZI/94).

In appearance, the Imprint compositions should be homogeneous and free of foreign inclusions before curing, and after curing, their surface should be smooth, even, and have no cracks. The color and appearance (shape) of the coating is specified when ordering.

ND materials are significantly stronger than standard materials C. It should be noted that the results will vary depending on the temperature conditions in which the samples are located; it is necessary to avoid overheating of the material.

The Imprint coating can be applied to any surface made of metal, wood, concrete, etc., and practically does not require special preparation of the work surface. The exception is the paving stones, which should not be coated directly due to poor adhesion with the coating.

The Imprint coating is recommended to be applied to a clean and dry surface, therefore, before application, the working surface must be cleaned by purging with compressed air and dried using special gas burners operating under high pressure. When applying the Imprint, the working surface does not require special sandblasting or shot blasting.

The Imprint material is applied directly to the cleaned and dried surface, without pretreatment with any primer. The Imprint coating smooths out all the irregularities of the base and does not require application of additional racking course.

When installing raised coatings from Imprint (the so-called "speed bump"), in order to save material, it is recommended to pre-perform an additional layer of the base (soil, crushed stone, concrete, asphalt), on which a polymer coating is applied.

Before applying the coating, the material is pre-placed in a special kocher (mixer) with vertical batching and heating. The mixture is heated to a temperature of 190-220 °C; it is very important to maintain the specified temperature.

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The heated mixture is poured into a pre-prepared formwork, after which it is pulled apart and leveled with squeegee, providing a given layer thickness (from 10 to 25 mm).

Before the material finally polymerizes and hardens, shaped impressions are made on the surface of the coating using specially made molds.

The applied coating polymerizes quickly enough and gains the necessary strength. Traffic on the arranged surface can be opened within 45 minutes after laying.

Required pace of work: $Vpw = L/[Ts - (\sum tloss)]$, m/cm or m/day, (1)

where Ts — specified construction period; tloss — (loss of time due to bad weather (tbw); flow mobilization (tmob); days off (td.off); time of routine break (trb); reserve time (tres).

2. The length of the work zone (awz) or (a) — the area in which one specialized unit performs the entire set of work assigned to it. It must be equal to Vpw or exceed it.

3. Time of the flow mobilization tmob is the time from the first private flow entering the road to the last private flow entering it: $tmob = ts\ [(n-1)+m+k]$, (2)

where ts — flow step (time to complete one work zone; for ts=1, the work zone is completed for 1 shift; for ts =0.5 — for half shift); n — the number of private flows; m — the number of reserve work zones; k — the number of routine breaks per work zone.

4. The length of the complex flow (or the front of work in progress):

Lfr= $\sum$ an +$\sum$am +$\sum$ak — the total number of main work zones, reserve work zones, and routine breaks per work zone.

5. Period of steady flow: $Tst = Ts - (tmob + tdemob)$. (3)

During the period of steady flow, finished products are issued.

Flow parameters are shown in Figure 2.

Non-flow method is used in the construction of areas of small length, when the time of flow mobilization is commensurate with the construction time, and also in areas with large concentration of work (deep excavations, high embankments, approaches to bridges and overpasses, etc.). It is common in the overhaul and reconstruction of roads, when the work area is limited and does not allow the flow to be expanded to a length Lfr.

Advantages of a flow-line method**:**

1. High quality of work, caused by its narrow specialization.
2. Finished products are issued continuously (in the case of a non-flow method, a gravel base can be laid on the whole area, on which cars will run, and it will be contaminated before laying asphalt concrete).
3. The pace of construction is significantly higher than with a non-flow method.

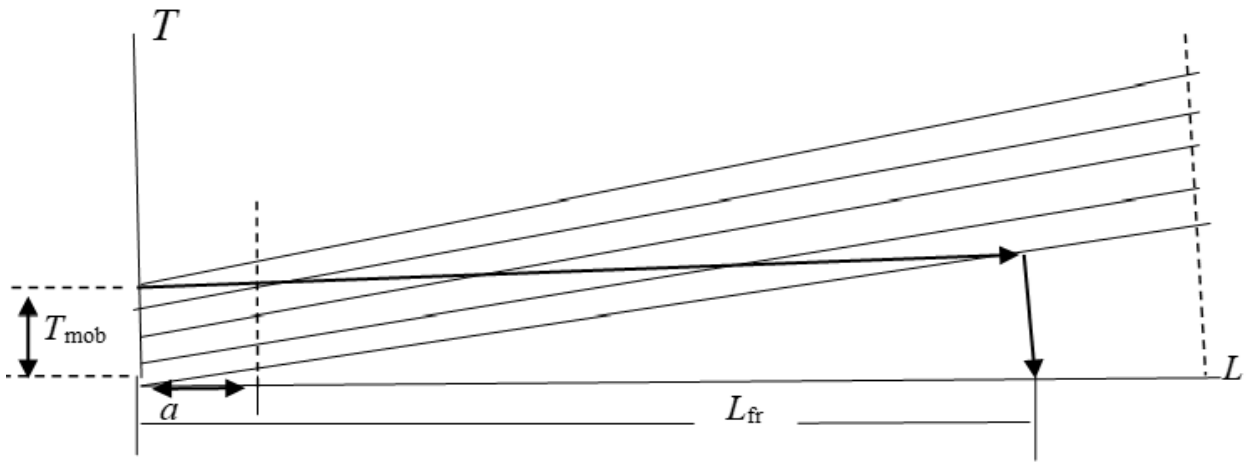

Figure 2.
Parameters of the flow-line method of work organization.

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3.1. Disadvantages of a Flow-Line Method:

1. The presence of the mobilization period, when the equipment of the latest flows stands idle.

2. The large length of Lfr, which reaches several kilometres, does not allow it to be used for the overhaul and reconstruction of roads along which the transit movement of cars does not stop.

3. The need for an equipment in the flow-line method is significantly higher than that of the non-flow method. Disadvantages of the flow-line method are advantages of the non-flow method and vice versa. The same can be said about the advantages of both methods. The way of work mobilization characterizes not the arrangement of equipment and workers within the flows, but the arrangement of construction organizations and enterprises along the length of the road under construction.

There are two ways of mobilization of road construction work:

- "From the head" or from one point;
- On a wide front.

The essence of these ways is shown in Figure 3 and Figure 4. The second way is characteristic for the construction of long roads, when they pass through the territories of several administrative territorial entities, each of which builds a section of the road using its own road-building organizations on its own territory. This is how the roads Don, Crimea, Amur and others are built. The mobilization of work on a wide front allows reducing the time of commissioning of the road.

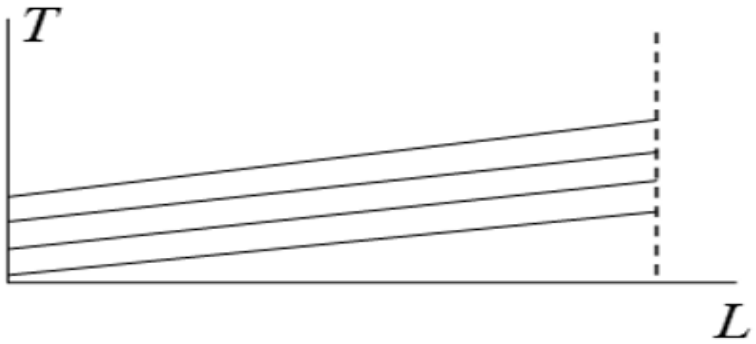

Figure 3.
Way of mobilization "from the head".

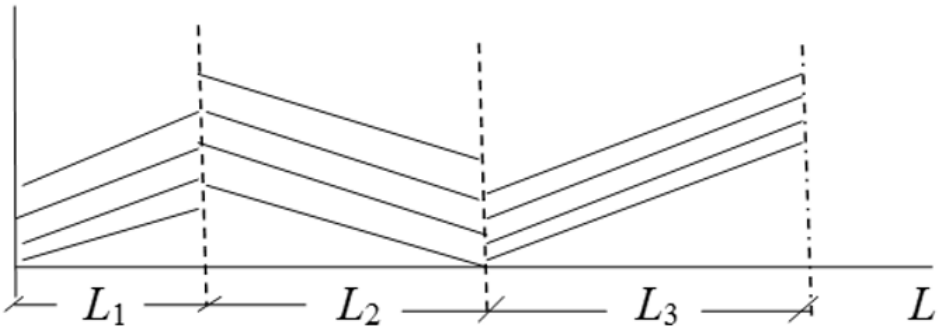

Figure 4.
Mobilization of work on a wide front.

4. Discussion

First of all, it is necessary to deal with the very concepts of "Organization of construction" and "Organization of construction work". They are interpreted differently in different sources (Figure 5).

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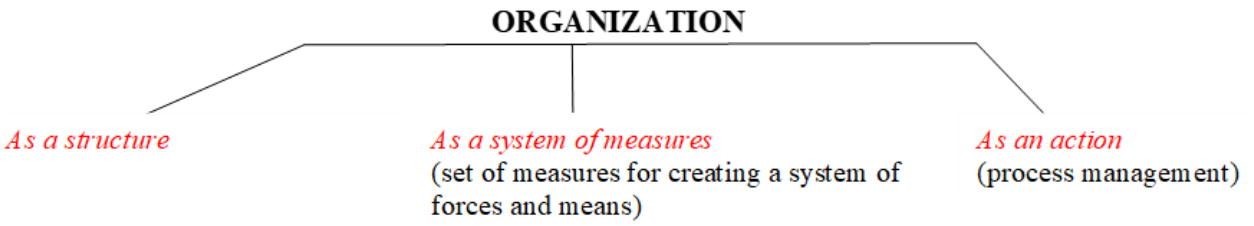

Figure 5.
"Organization of construction" and "Organization of construction work"

Today, there are no strict methods for assessing the efficiency of work organization methods. One of them was proposed by Professor Mogilevich V.M. (SIBADI) in the 70s of the last century. It is based on the calculation of the coefficient of conditional efficiency of the flow Ef:

$$Ef = Tst/Td = [Td - (tmob + tdemob)]/Td, \quad (4)$$

where Tst and Td — the time of the steady flow and the directive period for the construction of the road, respectively. It is obvious that Ef is less than 1.0, and the flow efficiency is higher if Ef is closer to unity.

The author recommends the following intervals of the values of Ef and the levels of efficiency associated with it:

with Ef > 0.7, the flow-line method is effective;
with 0.30 ≤ Ef ≤ 0.7, both methods of work organization are equally effective;
with Ef ≤ 0.3, the non-flow method is more efficient.

This approach does not stand up to strict criticism for the following reasons:

- The SIBADI methodology uses only one efficiency criterion - the time of work performance. In the market conditions, it is not the main one, since the main are economic criteria (construction cost, profit, profitability);
- The values of Ef are accepted "a priori" and do not have a strict justification.

Apparently, the assessment of efficiency of the organization method and the way of work mobilization should be based on a set of criteria (economic, mathematical and production), which should include: cost and actual cost of work, profit and profitability, the level of use of fixed production assets, taking into account their idle time in the period of mobilization and demobilization of works, completion date of the construction (Volkov, et al., 2015a, Volkov, et al., 2015b, Volkov, et al., 2015c, Lyovin, et al., 2016).

5. Conclusions

The organization of the production base and ensuring its rhythmic work largely determine the rhythm of the construction process, its technical and economic indicators. In recent years, calculation methods have appeared, which are based on probabilistic planning and the use of economic and mathematical methods for designing transport structures. In modern studies (Del Pizzo et al., 2021), considerable attention is paid to the noise characteristics of road surfaces. In particular, the sound of tire friction on the coating (Tyre Cavity Noise) is being studied. So, the relationship between the sound of tire friction and the parameters of the road surface is modeled. Special measurements of the texture of the road surface are made. Unfortunately, the acoustic quality of the Imprint coating has not been measured. At the same time, such measurements would be very useful, since acoustic characteristics represent a rather important aspect of the integral efficiency of the functioning of road surfaces. In particular, measurements could be carried out by the close proximity method (CPX). In modern conditions, the use of modern road surfaces is very important for temporary roads on the construction site, this reduces their wear during construction and avoids accidents or additional costs for road restoration, which ultimately leads to an increase in the cost and duration of construction. As a result of the conducted research, it was found that Imprint road surfaces meet the requirements for strength,

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abrasion resistance and impact resistance, resistance to rutting and sliding, chemical resistance and hygiene.

It is recommended to use Imprint road surfaces for the construction of temporary roads on a construction site.

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