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PERFORMANCE OF ROLLER-COMPACTED CONCRETE PAVEMENT STRUCTURE WITH STABILIZED SOIL BASE LAYERS DURING SPRING THAW

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Abstract

Roller-compacted concrete is a type of concrete with significantly larger fine aggregates comparing to conventional concrete. Larger fine aggregates percentage in roller-compacted concrete leads concrete mix to be non-slip and to be compacted by rollers. Roller-compacted concrete is cost-effective and easy to construct. Roller-compacted concrete can be paved by typical asphalt paver which simplifies the construction technology and makes it similar to asphalt paving technology. It also has the strength and performance of conventional concrete or even higher. Due to all the advantages, the use of roller-compacted pavement in industrial areas and low-volume rural roads is very beneficial. Some specially designed roller-compacted concrete structures with cement and special additives stabilized subgrade and or base layers showed very good performance in road. Few experimental tests were made measuring surface deflection with falling weight deflectometer (FWD). The main aim of these experimental tests is to collect deflection values from roller-compacted structure and to compare them between different seasons of the year. Such experimental tests also helps to learn more about this type of pavement structure and how it performs during spring thaw when the bearing capacity of the pavement structure is usually lower comparing to the other seasons. In these paper surface deflection measurements was conducted on local road No. 130 in Lithuania, which was reconstructed in 2021. The bearing capacity of the pavement structure was measured in August 2021 and March 2022. The results have showed that the bearing capacity of the pavement structure increased 9 months after reconstruction and that hydrothermal conditions do not affect the bearing capacity of RCC pavement structure with stabilized subbase and base layers.

Keywords: falling weight deflectometer (FWD), concrete, roller-compacted concrete, deflection, paver

1 Introduction

Roller-compacted concrete (RCC) is dry mix concrete which can be laid down with asphalt paver and can be rolled by rollers for compaction. RCC consists of the same ingredients as conventional concrete but in different mixture proportion. Comparison of typical conventional and RCC mixture proportion are represented in Figure 1 [2].

RCC pavement compared with conventional concrete pavement is economical, easier to apply on site and faster to construct [3, 6]. RCC pavement structure requires less equipment and can be placed in a more time-efficient way than conventional concrete [7]. A lot of researchers have proved that mechanical properties of RCC such as compressive, flexural and shear strength can be higher than conventional concrete [4, 5]. In RCC pavement structures it is very important to have strong base which could withstand design load and environmen-

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tal conditions. Cement and special additives stabilized bases are the key solution to have proper base for RCC pavements. The main aim of stabilization is to obtain a much better performance of the bound layer by adding a relatively high amount of cement (up to 10 %) [8].

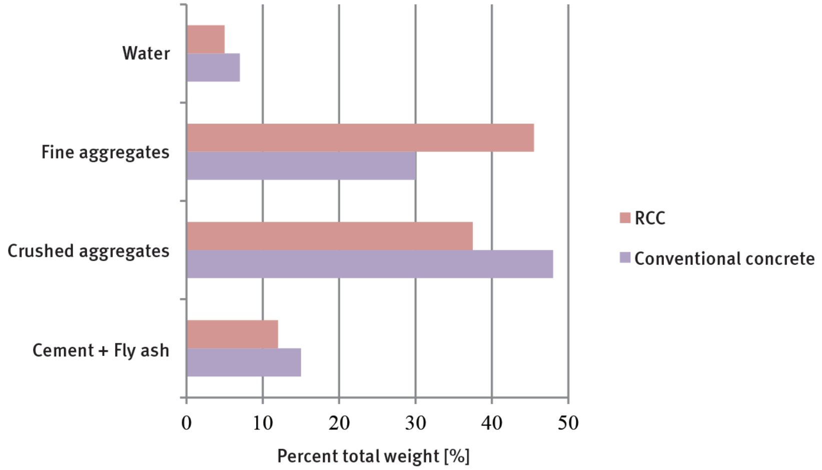

Figure 1 Mixture proportion comparison of RCC and conventional concrete

Modulus of cement-stabilized pavement base course is significantly influenced by cement content and curing time. The dynamic modulus can increase by 17 %, up to 46 %, if an additional 1 % and 2 % cement, respectively, is added to the stabilized material [9]. For instance, in Lithuania RCC pavement was used in zones to carry heavy load, for example in Klaipeda, Akmene Free Economic Zone due to a substantial cost savings over conventional concrete. RCC pavement was also used in low traffic volume road like private and local roads in Lithuania [1]. In Lithuania there is a big interest in RCC pavement structures, the most common used RCC pavement structure consists of [1]:

- 16 cm of RCC layer;
- 20-40 cm of cement and special additives stabilized base.

RCC pavement structure with cement and special additives stabilized base is new as a type of pavement structure used in Lithuania. When something new is on the market it is very important to make study of its performance not only in laboratory but on the real site with the real traffic, weather, hydrothermal conditions as well. To our knowledge, no study has conducted to investigate RCC pavement structures with cement and special additives stabilized base sensitivity to frost and change of pavement structure bearing capacity dependent on subgrade hydrothermal conditions. Such kind of study was made on Local road No. 130 in Lithuania, which is the main topic of this paper.

2 Experiment

2.1 Test site

The experiment to evaluate dependency of subgrade hydrothermal conditions to the bearing capacity of pavement structure with cement and special additives stabilized base and RCC course layer was conducted on a two-lane Lithuanian local road No. 130, which was reconstructed in 2021. Pavement structure was design with 20 cm cement and special additives stabilized subbase layer, 40 cm cement and special additives stabilized base layer and on the top of the base layer was laid RCC surface course with a thickness of 16 cm (Figure 2).

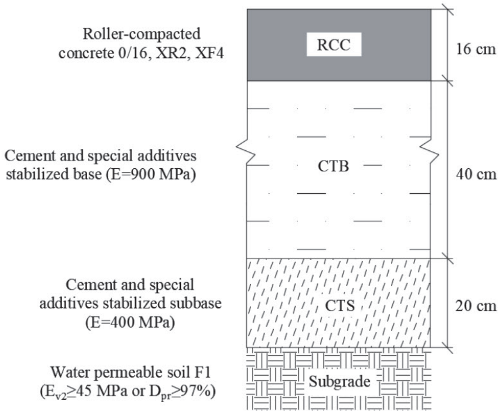

Figure 2 Pavement structure

2.2 Materials

Cement and special additives stabilized subbase consists of:

- 3-5 % portland cement;
- on exchange enhancing chemical additive Stabgrunt 1 (2) (0.2 l per m^3 of soil);
- water;
- soil.

Requirements for cement and special additives stabilized subbase:

- deformation modulus $E_{v2} \geq 100$ MPa;
- compressive strength after 28 days not less than 1.0 MPa;
- compaction rate not less than 98 %.

Cement and special additives stabilized base consists of:

- 3-8 % portland cement;
- on exchange enhancing chemical additive Stabgrunt 1 (2) (0.2 l per m^3 of soil);
- water;
- soil.

Requirements for cement and special additives stabilized subbase:

- compressive strength after 28 days not less than 1.5 MPa;
- the ratio of compressive strength of samples after refrigeration and thawing cycles to reference samples (after 28 days) is at least 0.6;
- compaction rate not less than 98 %.

The RCC mixture was produced in mobile concrete batching plant and consists of:

- 4/16 fraction crushed aggregates (48.8 %);
- 0/4 fraction fine aggregates (30.9 %);
- cement (14.7 %);
- water (5.5 %);
- concrete plasticizer (0.07 %).

2.3 Field testing

The bearing capacity of pavement structure was conducted using a falling weight deflectometer (FWD). The falling weight deflectometer (FWD) is non-destructive testing (NDT) device to evaluate the bearing capacity of the pavement, which is use widely all around the world. A FWD transfers a 50 kN and 200 kN load to the road pavement through a 300 mm diameter circular plate, which results in 707 MPa and 2829 MPa pressure. The generated haversine pulse lasts about 30 ms. Dynamic deflections on the road surface due to applied loads are captured by sensors (geophones), which are positioned at different distances from the center of the loading plate (0, 200, 300, 450, 600, 900, 1200, 1500 and 1800 mm).

The bearing capacity of the pavement structure was measured in August 2021 (28 days after reconstruction) and March 2022. Measurements were taken on each lane in the middle of right wheel trajectory and at 20 m interval in August 2021 and at 5 m interval in March 2022.

3 Results and discussion

The normalized surface deflection w_0 and normalized modulus E_0 measured with FWD with 50 kN and 200kN load are represented in Figure 3 and Figure 4.

As seen from Figure 3 and Figure 4 normalized surface deflection w_0 measured in August 2021 with 50 kN load on left lane varied from 72 mm to 180 mm, average was 105 mm, standard deviation – 41 mm. On right lane normalized surface deflection w_0 in August 2021 measured with 50 kN load varied from 63 mm to 164 mm, average was 97 mm, standard deviation – 32 mm. Normalized modulus E_0 measured in August 2021 with 50 kN load on left lane varied from 1035 MPa to 2574 MPa, average was 1959 MPa, standard deviation – 596 MPa. On right lane normalized modulus E_0 in August 2021 measured with 50 kN load varied from 1138 MPa to 2957 MPa, average was 2061 MPa, standard deviation – 567 MPa. Surface deflection w_0 measurements, which were carried in March 2022 (spring thaw) with 50 kN load showed variation on left lane from 36 mm to 99 mm, average was 55 mm, standard deviation – 15 mm. On right lane normalized surface deflection w_0 in March 2022 (spring thaw) measured with 50 kN load varied from 38 mm to 64 mm, average was 49 mm, standard deviation – 8 mm. Normalized modulus E_0 measured in March 2022 (spring thaw) with 50 kN load on left lane varied from 1876 MPa to 5139 MPa, average was 3573 MPa, standard deviation – 869 MPa. On right lane normalized modulus E_0 in March 2022 (spring thaw) measured with 50 kN load varied from 2913 MPa to 4914 MPa, average was 3925 MPa, standard deviation – 606 MPa.

As seen from Figure 3 and Figure 4 normalized surface deflection w_0 measured in August 2021 with 200 kN load on left lane varied from 309 mm to 551 mm, average was 442 mm, standard deviation – 89 mm. On right lane normalized surface deflection w_0 in August 2021 measured with 200 kN load varied from 315 mm to 516 mm, average was 411 mm, standard deviation – 71 mm. Normalized modulus E_0 measured in August 2021 with 200 kN load on left lane varied from 1353 MPa to 2408 MPa, average was 1752 MPa, standard deviation – 381 MPa. On right lane normalized modulus E_0 in August 2021 measured with 200 kN load varied from 1443 MPa to 2362 MPa, average was 1859 MPa, standard deviation – 322 MPa. Surface deflection w_0 measurements, which were carried in March 2022 (spring thaw) with 200 kN load showed variation on left lane from 179 mm to 394 mm, average was 273 mm, standard deviation – 62 mm. On right lane normalized surface deflection w_0 in March 2022 (spring thaw) measured with 200 kN load varied from 182 mm to 333 mm, average was 247 mm, standard deviation – 48 mm. Normalized modulus E_0 measured in March 2022 (spring thaw) with 200 kN load on left lane varied from 1888 MPa to 4165 MPa, average was 2863 MPa, standard deviation – 639 MPa. On right lane normalized modulus E_0 in March 2022 (spring thaw) measured with 200 kN load varied from 2235 MPa to 4099 MPa, average was 3925 MPa, standard deviation – 592 MPa.

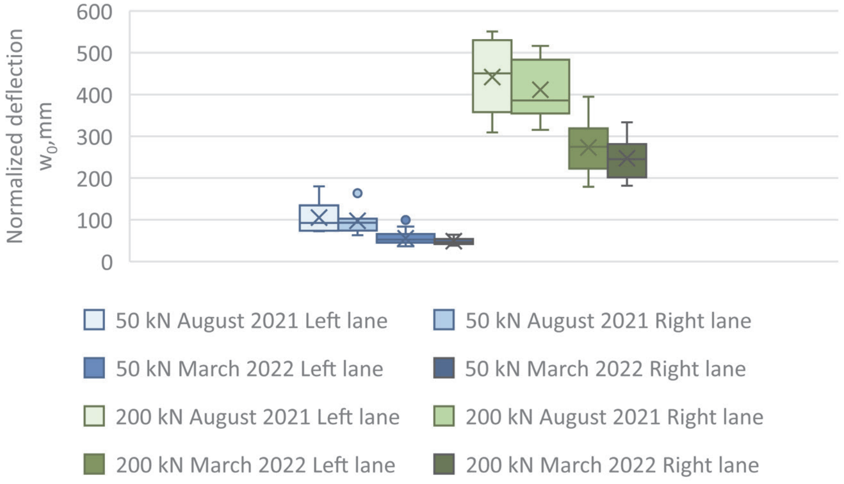

Figure 3 Normalized surface deflection w_0

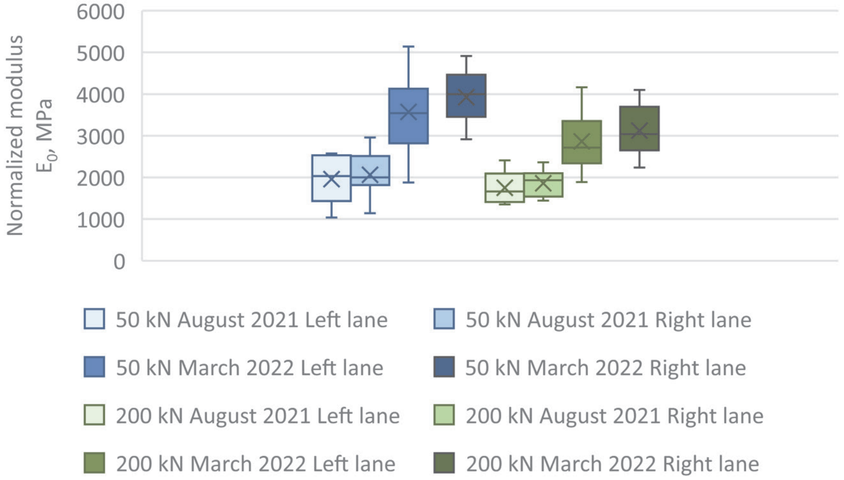

Figure 4 Normalized modulus E_0

Lower surface deflection w_0 and higher modulus E_0 9 months after reconstruction showed that the bearing capacity of the pavement structure increased. The main reason of that is that mechanical properties of hydraulically bounded layers are usually increasing with ages until they reach their maximum values.

4 Conclusions

The analysis of FWD data from different period of seasons led to the following conclusions:

- Normalized surface deflection w_0 measured in August 2021 with 50 kN load on left lane varied from 72 mm to 180 mm, average was 105 mm, standard deviation – 41 mm, on right lane varied from 63 mm to 164 mm, average was 97 mm, standard deviation – 32 mm. Surface deflection w_0 measured in March 2022 (spring thaw) with 50 kN load showed variation on left lane from 36 mm to 99 mm, average was 55 mm, standard deviation – 15 mm, on right lane varied from 38 mm to 64 mm, average was 49 mm, standard deviation – 8 mm. Normalized surface deflection w_0 measured in August 2021 with 200 kN load on left lane varied from 309 mm to 551 mm, average was 442 mm, standard deviation – 89 mm, on right lane varied from 315 mm to 516 mm, average was 411 mm, standard deviation – 71 mm. Surface deflection w_0 measured in March 2022 (spring thaw) with 200 kN load showed variation on left lane from 179 mm to 394 mm, average was 273 mm, standard deviation – 62 mm, on right lane variation from 182 mm to 333 mm, average was 247 mm, standard deviation – 48 mm.

- Normalized modulus E_0 measured in August 2021 with 50 kN load on left lane varied from 1035 MPa to 2574 MPa, average was 1959 MPa, standard deviation – 596 MPa, on right lane varied from 1138 MPa to 2957 MPa, average was 2061 MPa, standard deviation – 567 MPa. Normalized modulus E_0 measured in March 2022 (spring thaw) with 50 kN load on left lane varied from 1876 MPa to 5139 MPa, average was 3573 MPa, standard deviation – 869 MPa, on right lane varied from 2913 MPa to 4914 MPa, average was 3925 MPa, standard deviation – 606 MPa. Normalized modulus E_0 measured in August 2021 with 200 kN load on left lane varied from 1353 MPa to 2408 MPa, average was 1752 MPa, standard deviation – 381 MPa, on right lane varied from 1443 MPa to 2362 MPa, average was 1859 MPa, standard deviation – 322 MPa. Normalized modulus E_0 measured on March 2022 (spring thaw) with 200 kN load on left lane varied from 1888 MPa to 4165 MPa, average was 2863 MPa, standard deviation – 639 MPa, on right lane varied from 2235 MPa to 4099 MPa, average was 3925 MPa, standard deviation – 592 MPa.
- Surface deflection w_0 in the center of the load 50 kN on RCC pavement structure with 20 cm cement and special additives stabilized subbase layer, 40 cm cement and special additives stabilized base layer and RCC surface course with a thickness of 16 cm was between 33-38 % lower on March 2022 (spring thaw) than on August 2021 (28 days after reconstruction). The same tencency concluded with the 200 kN load with the diference between March 2022 (spring thaw) and August 2021 (28 days after reconstruction) with deflection of about twice lower.
- Comparison of RCC pavement surface deflections measured on Local road No. 130 with surface deflection measurements, which were conducted on pretty thick asphalt pavement structure (24 cm AC layer, 24 cm crushed aggregate base and 30 cm subbase) by other researchers [10], showed about two times smaller surface deflections on Local road No. 130.
- Based on two years measurements it can be stated that hydrothermal conditions do not affect the bearing capacity of RCC pavement structure with stabilized subbase and base layers which constructed on water permeable subgrade. Lower surface deflection w_0 9 months after reconstruction showed that the bearing capacity of the pavement structure increased. The main reason of that is that mechanical properties of hydraulically bounded layers are usually increasing with ages until they reach their maximum values.

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