Calculation of base loadings of cement concrete roads in extreme continental climate conditions

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Abstract. In Kazakhstan, the construction of more than 1,600 kilometers of cement concrete roads in various regions over the past 15 years has made a significant contribution to improving the country's transport infrastructure. This development is driven by the strategic importance of transport corridors and the increasing intensity of truck traffic, which requires improved transport efficiency, safety and environmental sustainability. The modernization of road infrastructure not only increases the efficiency of vehicles and the speed of cargo delivery, but also plays a crucial role in sustainable economic development, attracting investment, expanding trade and increasing the competitiveness of regional economies. This article examines the importance of cement concrete roads in the transport network of Kazakhstan and their role in achieving these goals. In particular, it emphasizes the need to use high-quality building materials, including modified concretes with improved performance, for road construction projects. In addition, the article discusses modern high-strength concrete mixtures and their composition, emphasizes the importance of accurate dosing to achieve the desired technical characteristics and properties. Overall, this study highlights the crucial role of cement concrete roads in the development of Kazakhstan's transport infrastructure, promoting economic growth and mitigating environmental impacts through efficiency and sustainability measures.

1 Introduction

In Kazakhstan, over the last 15 years, more than 1600 kilometres of DH roads have been constructed. In particular, there are CBR roads in Akmola, Karaganda, Pavlodar, Almaty, Zhambyl and Turkestan regions. Construction of these CS roads is conditioned by transport and logistics corridors of the Republic of Kazakhstan and the intensity of truck traffic. To increase the efficiency of transport vehicles, speed of cargo delivery and passenger transport, comfort and safety of traffic, as well as to reduce the cost of transport, it is

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necessary to radically improve the transport and operational qualities of highways and urban streets.

In addition, the development and modernisation of road infrastructure plays a key role in Kazakhstan's sustainable economic development, helping to attract investment, expand trade and increase the competitiveness of regional economies. Road improvements also have a positive effect on the environmental situation in the country, reducing emissions of harmful substances into the atmosphere and improving the quality of the environment.

The construction of cement concrete roads requires the use of quality construction materials, including modified concretes with improved performance. Self-compacting concrete has superior characteristics that increase efficiency and improve working conditions by eliminating the need for vibration and compaction [1]. Modern high-strength concrete mixes used for cement concrete road construction are a complex system of various components including cement, aggregates, additives and water. These components are mixed in certain proportions to achieve the desired specifications and properties of the concrete mix [2].

2 Methods

Modern road construction involves not only the physical construction of pavements, but also in-depth geotechnical analyses to ensure the stability and durability of the foundations [3]. For this purpose, engineers’ resort to the use of specialised software products that allow them to simulate different types of loads and analyse the impact on the bases of road structures [4,5,6].

PLAXIS, Geostudio, Midas GTS/NX, PLATEIA are widely used among such software tools. For example, Geostudio is a software suite that includes a number of tools for geotechnical analysis and modelling. It is widely used by engineers and designers to solve various problems related to geotechnical and engineering structures, including road foundations.

Geostudio is a powerful and versatile tool for engineers involved in the design and construction of road infrastructure, providing the ability to perform accurate and reliable calculations and analyses, as well as optimise designs and structures to ensure stability, durability and safety.

LIRA-CAD 2017 (LIRA-CAD 2017 PC) is a multifunctional software package for calculation, research and design of structures for various purposes. LIRA-CAD 2017 PC is successfully used for calculations in construction, mechanical engineering, bridge building, nuclear power engineering, oil industry and in many other areas where the methods of structural mechanics are relevant.

The newest representative of the LIRA family is LIRA-CAD 2017 PC. In addition to the general calculation of the object model for all possible types of static loads, temperature, deformation and dynamic effects. LIRA-CAD 2017 PC automates a number of design processes: determination of design combinations of loads and forces, assignment of structural elements, selection and verification of sections of steel and reinforced concrete structures with the formation of sketches, drawings of columns and beams [7,8].

PLAXIS is a finite element analysis software system used for solving geotechnical engineering and design problems. It is a package of computational programmes for finite element calculation of the stress-strain state of structures, foundations and bases. In this programme we have created a model of a section of road pavement for finite element calculation of the stress-strain state of the foundation and pavement [9,10].
3 Results

The calculation was performed in the PLAXIS numerical modelling program, stress and strain diagrams were obtained in the pavement and ground bases; the calculation was carried out on a section of cement concrete road in the southern region of Kazakhstan due to the fact that the source documents (geological surveys) were available for this direction [11,12,13].

Fig. 1. Effective average tangential stress on a cement concrete road section in the southern region of Kazakhstan.

On the mosaic of stress eps are presented the results of stresses in the soil from a load of 160 kN with the obtained output data where the maximum stress occurs in the road layers of light loamy soils and the layer of HPS. The maximum stresses reach up to 26 kN/m².
Relative tangential stress occurs directly under the road and is distributed over gravel soils, which due to their higher strength carry the main load from the road.

Fig. 3. Extreme average stress on a cement concrete road section in the southern region of Kazakhstan.
Fig. 4. Total incremental deformation on a cement concrete road section in the southern region of Kazakhstan.

Fig. 5. Horizontal strain increments on a cement concrete road section in the southern region of Kazakhstan.
Fig. 6. Vertical strain increments on a cement concrete road section in the southern region of Kazakhstan.
Fig. 7. Volumetric deformations on a section of cement concrete road in the southern region of Kazakhstan.

The analysis showed that stresses and deformations occur directly at the point load contact point with a trapezoidal shape along the depth of influence. The horizontal strain isopoles characterise the shear isopoles towards the kerb.

According to the calculations performed, mosaics of strain and stress epiphures were obtained. The tangent stress mosaics show that the stresses spread linearly over the pavement and the loam subgrade, and then there is a non-linear stress concentration in the hard gravel subgrade [14]. The mosaics of relative tangential stresses show that the stress epiphyses propagate with a broadening of the zone of influence in the form of a trapezoid and propagation through the gravel soil layer. According to the mosaics of the total deformation eupyres it is revealed that the subsidence occurs linearly on the road surface and ground layers of the base, but in the road slopes there is a bulging of soils due to loading of the roadbed [15,16]. According to the mosaics of volumetric deformation patterns, it is revealed that volumetric deformations occur directly under the roadbed, and volumetric bulging deformations occur in the asphalt roadbed between the carriageways.

Discussion

A review of research by scientists confirms the dependence of deformation of cement concrete slabs as a result of temperature changes. A negative temperature differential, meaning that the temperature of the top of the slab is lower than the temperature of the bottom of the slab, forces the slab to curl upwards at the edges, and thus the corners experience the most curling [17].

At this point, the centre is in contact with the base. A positive temperature differential, on the other hand, produces the opposite results. Thus, if a negative temperature difference results in high thermal tensile stress at the centre of the cement concrete slab, and a positive temperature difference results in high thermal compressive stress near the centre. In both cases, parts of the cement concrete slab are not in direct contact with the subgrade, and from the bending of the transport load, the tensile stresses in the cement concrete pavement may increase. Since the tensile strength of concrete is low compared to the compressive strength, the combined tensile stress caused by temperature gradient and traffic load can easily crack the pavement. Moreover, in a long cement concrete slab, crack formation may occur haphazardly.

To control random cracking in cement concrete pavements, the current practice is to cut a joint about 1/3 or 1/4 of the thickness of the CB pavement in the concrete pavement when the pavement is 1 to 3 days old. When the pavement is free to traffic, natural cracking may occur at the location where the temperature joint is installed, depending on the amount of heat that is caused by changes in the temperature and properties of the concrete. A certain depth of the joint must be provided so that transverse cracks cannot form beyond the location of the joint. If the depth is not deep enough, cracks will form beyond that joint, resulting in costly future maintenance and repairs [18,19].

In order to better understand the factors that influence cracking in CB pavements, parametric studies have been carried out and a special programme has been developed to estimate the material properties required for the theoretical models [20].

Conclusion

Cement concrete motorways play an important role in the infrastructure of the transport network, ensuring efficient and safe movement of trucks and cars. Nowadays, modern
technology and innovative methods play a key role in improving the quality, durability and efficiency of cement concrete motorways.

The introduction of automated paving and compaction methods, such as automated concrete pavers and intelligent compaction control systems, makes it possible to achieve high accuracy and uniformity of the road surface. This reduces lead times, minimises resource costs and ensures improved quality of road infrastructure.

Overall, modern technologies and innovative methods play a key role in improving cement concrete roads, providing an optimal combination of environmental sustainability, economic efficiency and high pavement quality. Further development and application of new technologies in this field will contribute to improving the infrastructure of the transport network and increasing the level of comfort and safety on the roads.

References

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