The effect of increasing loads on foundations of operating bridges

S. S. Salixanov*, *F. Z.* Zokirov, *Y. T.* Xakimova, and *G. B.* Ismailova

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. This article examines the road bridge over the Karadarya River on the 5th km of the exploited Andijan – Pakhtaabad route R135 Highway. In this case, the effect on the load-bearing capacity of its foundation on ShNQ 2.05.03-12, which is currently in effect, on the replacement of the bridge Intermediate Unit (highway bridge designed and built according to the temporary load classes N30 and NK-80, N10 and NG60) into the temporary load class A14 and NK-100, or on the load-bearing capacity of the Intermediate Unit in increasing its load capacity, was considered. Recommendations have also been made on the maximum increase in the class of permanent and temporary load falling on the foundation of this bridge, which is in operation.

1 Introduction

Recently, the mass and intensity of traffic of vehicles circulating on the roads of our republic have been increasing, and their larger increase is also expected shortly.

In the adopted 1997 norms KMK 05.03-97 "Bridges and pipes" for the design of road bridges and overpasses, A-11, NK-80, and pedestrian loads were taken as the main temporary loads. In 2012, these standards were amended. In the new currently valid SHN 05.03-12 "Bridges and Pipes", A-14, NK-100, and pedestrian load were adopted as the main live loads, i.e., significantly increased the class of temporary loads.

Currently, only 14,000 bridges are in operation in our republic. Of this number of bridges, 68%, i.e., 9 900 pcs built in 1960-1970, of which 5,476 units require repair. These bridges were designed and built according to the old normative documents to pass temporary loads of a lower class. In this regard, there are problems in passing modern loads through them. An urgent issue is on the agenda - an increase in the bearing capacity of the span structures of previously built bridges to ensure the passage of existing standard live loads.

To radically improve the condition and operation of these bridges following modern requirements, several resolutions of the President of the Republic of Uzbekistan were adopted, incl. PP-3309 of 04.10.2017 "On improving the system for organizing the operation and construction of road bridges, overpasses, and other artificial structures", PP-3632 of 03.29.2018 "On approval of the State program for the construction, reconstruction, and overhaul of road bridges, overpasses, and other artificial structures in the Republic of Karakalpakstan and in Tashkent in 2018–2022", PP-4545 dated December 09, 2019 "On

*Corresponding author: sssalixanov@mail.ru

measures to further improve the management system of the road industry", etc.

To pass modern loads through road bridges in operation to ensure their normal operational condition, it is necessary to increase the bearing capacity of span structures, which requires making appropriate changes to their design. This causes an increase in the action of permanent and temporary loads on the bridge structure. On the other hand, this factor also has a corresponding effect on the operation of the yoke supports, i.e., support works under the influence of increased loads. Therefore, it is advisable to check the bearing capacity of the supports of operating bridges, operating under the influence of loads increased by a certain amount caused by changes in the design of span structures.

2 Objects and methods of research

Several technical solutions have been proposed to increase the bearing capacity of the span structures of currently operated bridges, designed and built according to the standards that have now lost their effect to ensure the above regulations. In some cases, appropriate work is being done to address this issue. For example, it is proposed to use in practice the replacement of an old superstructure with a new one, designed and manufactured following current standards. Another method proposed by the authors of this article is to increase the bearing capacity of spans of operating bridges by increasing the working height of the main beams of spans without dismantling them [1].

Following the regulatory document GOST 33178 - 2014 of the Interstate Council for Standardization, Metrology, and Certification, the operational service life of bridge spans is determined as, on average, 50 years. This normative service life of bridge structures is relative because this period may be extended or shortened in direct connection with the operating conditions.

Based on this, it can be said that when replacing or increasing the bearing capacity by other methods of bridge spans designed and in operation for 35–45 years, it is necessary to assess the bearing capacity of their supports and foundations for the impact of increased permanent and modern temporary loads.

For example, consider a road bridge across the Karadarya River at the 5th kilometer of the R135 highway along the Andijan–Pahtaabad highway. This bridge was operated in 1982; the bridge scheme is 6 x 24 m. The span structure of the bridge was designed and built according to the regulatory documents in force in 1962–1984 for live loads H30, NK-80, H10, and NG60. Intermediate bridge supports on shallow foundations (Fig. 1).

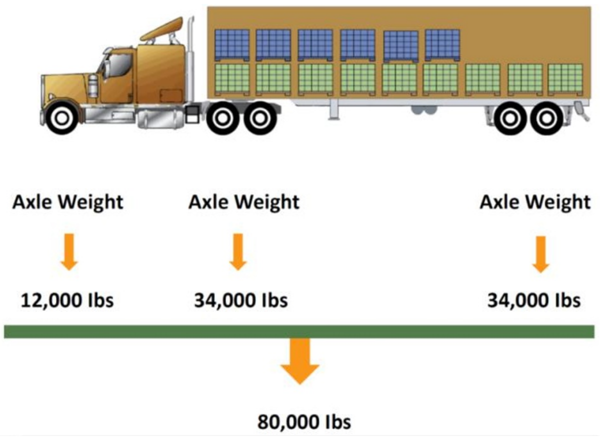

Fig. 1. Load trailers and distribute weight, NK-80

Given the location of this bridge on an intercity highway, it is necessary to decide to replace its span with a new one, i.e., designed and manufactured according to the norms of ShNK 2.-05.03–12 "Bridges and Pipes" that are valid to this day for live loads A14 and NK-100 or to increase the bearing capacity of the old span structure by our proposed method (Fig. 2) [1].

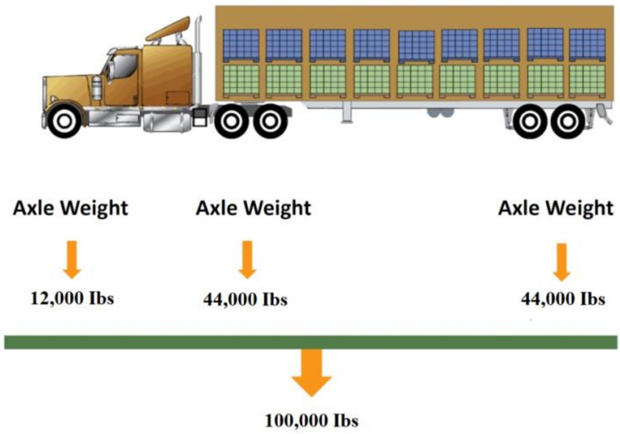

Fig. 2. Load trailers and distribute weight, NK-100

With an increase in the bearing capacity of span structures by the two methods proposed above, an increase is observed not only in the temporary load but also in the constant load (Fig. 3). Therefore, it is necessary to carry out appropriate calculations to reassess the bearing capacity of the foundations of the bridge supports.

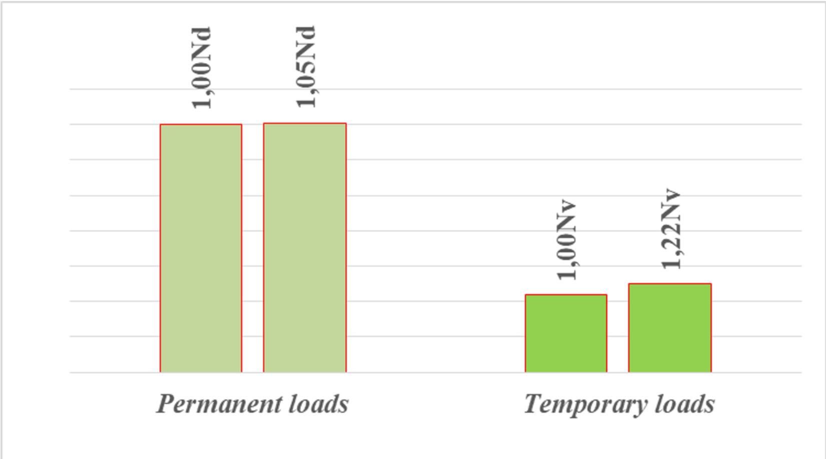

Fig. 3. Dynamics of growth in the value of permanent and temporary loads with an increase in the bearing capacity of the span structures of the bridge

3 Results and Discussion

The calculations carried out for the above bridge showed that with an increase in the bearing capacity of the spans by the method proposed by us [1], the growth of permanent and temporary loads on the foundations of the supports is, with an error of ± 1%, respectively 5% and 22%, i.e., the growth of permanent loads compared to the growth of temporary loads is 4 times less.

Following the standards, the dimensions of the shallow foundation of a bridge structure are determined by the following formulas:

1) Estimated area of the base of the foundation:

$$A_{\max} = b_{\max} \cdot a_{\max}$$

2) The required area of the base of the foundation to carry the design load:

$$A_t = \frac{kN_{oI}}{\frac{R}{1.4} - h_f \cdot \gamma_{mt}}$$

3) Allowable range of calculated and required areas of the base of the foundation:

$$\delta = \frac{A_{\max} - A_t}{A_t} \cdot 100\% = \pm 5\%$$

If this condition is not met, a recalculation with a change in the dimensions of the foundation is required.

Here: $k = 1.4$ is load safety factor;

γ_{mt} = 20 kN/m^3 is bulk density of the support material;

h_f is foundation height;

R is calculated soil resistance;

N_{oI} is combination of increased permanent and temporary loads acting on the foundation area.

The results of the calculations show the difference between the required and calculated areas of the base of the foundation of the supports of the considered bridge in the amount of 4.98% (see Table 1). With an increase in permanent and temporary loads by 10%, the difference between the required and calculated areas is 4.56%. These values correspond to the range of permissible values. The dynamics of changes in the required areas of the base of the foundation are shown in Fig.4.

Table 1. Change in the difference between the required and calculated areas of the base of the foundation with increasing loads

№	N	k	kN	A_t	A_{max}	δ
1	7009.7	100%	7009.700	46.60	48.92	4.98%
2	7009.7	101%	7079.797	47.06	48.92	3.94%
3	7009.7	102%	7149.894	47.53	48.92	2.92%
4	7009.7	103%	7219.991	48.00	48.92	1.92%
5	7009.7	104%	7290.088	48.46	48.92	0.94%
6	7009.7	105%	7360.185	48.93	48.92	-0.02%
7	7009.7	106%	7430.282	49.39	48.92	-0.96%
8	7009.7	107%	7500.379	49.86	48.92	-1.89%
9	7009.7	108%	7570.476	50.33	48.92	-2.79%
10	7009.7	109%	7640.573	50.79	48.92	-3.69%
11	7009.7	110%	7710.670	51.26	48.92	-4.56%

1) Bearing capacity of one reinforced concrete pile:

$$P'_d = \frac{F_d}{\gamma_k}$$

2) Maximum load per reinforced concrete pile:

$$N_{\max/\min} = \frac{N_d}{n} \pm \frac{M_{xyi}}{\sum y_i^2} \pm \frac{M_{yxi}}{\sum x_i^2}$$

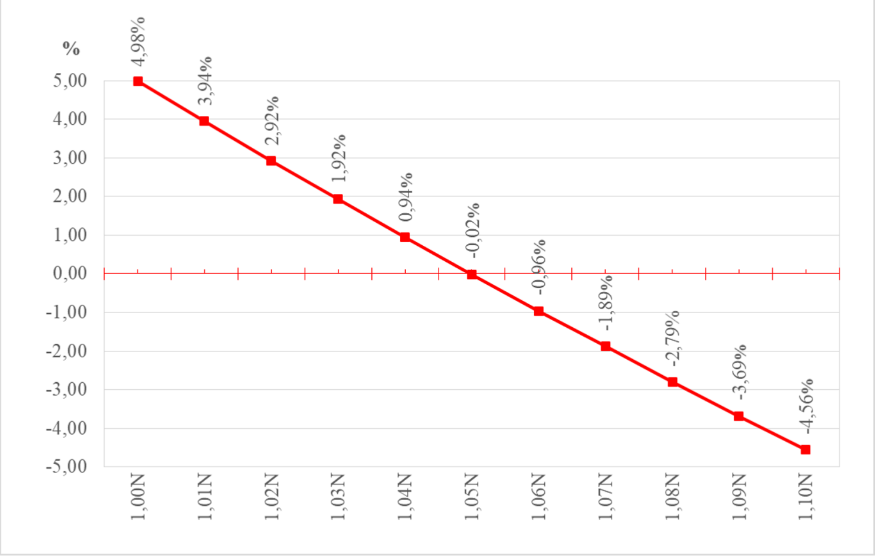

Fig. 4. Dynamics of changes in the required areas of the base of the foundation with an increase in the load on the foundation

3) Allowable range of difference between the current loads on one reinforced concrete pile and its bearing capacity:

$$\delta_N = \frac{N - P_d'}{P_d'} \cdot 100\ \% = +5\% \div -15\%$$

The results of the calculations for the considered bridge show the difference between the current load on one reinforced concrete pile. Its bearing capacity in the amount of – 14.782% (Fig. 5). With an increase in the values of permanent and temporary loads up to 24%, the difference between the actual load on one reinforced concrete pile and its bearing capacity was + 4.555%. These defined values are within the allowable range of + 5% ÷ – 15%, and therefore it can be said that the condition of the considered deep foundation meets the operational requirements.

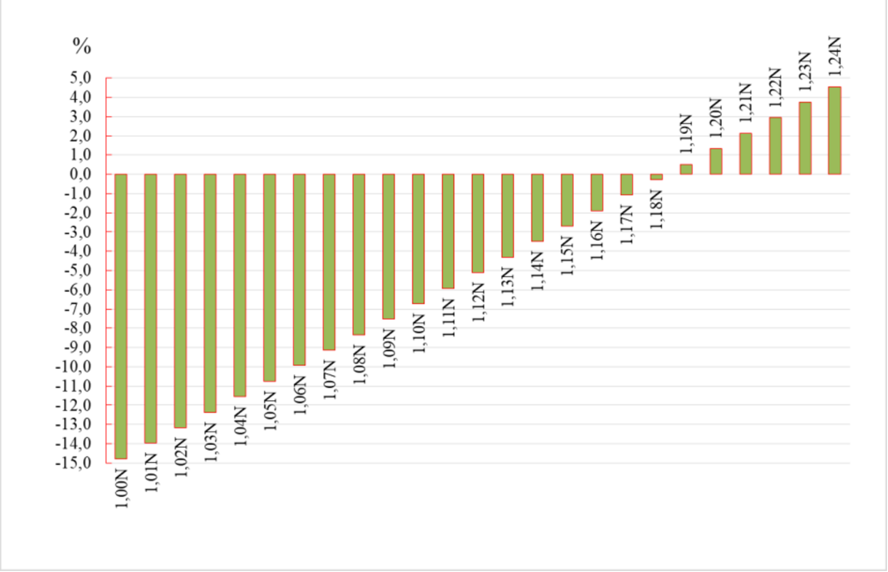

Fig. 5. Growth dynamics of the allowable difference between the load on the pile and its bearing capacity with an increase in permanent and temporary loads

4 Conclusion

With an increase in the bearing capacity of the spans of bridges designed and built according to the method proposed by us, the performance characteristics of the bearing elements and the base of the bridge are significantly improved. These structures can meet high requirements with up to 24% increase in permanent and live loads. The sharp increase in permanent and temporary loads acting on foundations from modern heavy vehicles and cargo does not affect the flexibility and bearing capacity of properly designed bridge elements. The value of the load safety factors remains unchanged and an increase in the values of permanent and temporary loads will not lead to a decrease in the service life of bridge foundations. The dimensions of the sole of the shallow foundation do not need to be changed.

References

1. Salixanov S. Yashchuk M., and Smerdov D. Reinforced concrete elements strengthened by pre-stressed fibre-reinforced polymer (FRP). Transportation Research Procedia, 54, 157-165. (2021).
2. Saidxon S., Fakhriddin Z., and Nodirbek A. A new type of construction of the carriageway of road bridges using non-traditional waterproofing materials. Science and innovation, 1(C3), 208-213. (2022).
3. Salikhanov S., Pulatova Z., Zakirov F., Rahimjonov Z., and Abdullayev A. Determination of deformations and self-stress in concrete on stress cement. In E3S Web of Conferences, Vol. 264, p. 02056. (2021).
4. Shermuxamedov U. Z., Zokirov F. Z. Application of modern, effective materials in rail road reinforced bridge elements. Journal of tashkent institute of railway engineers. Vol. 15(3). pp. 8-13. (2019)
5. Raupov C., Karimova A., Zokirov F., and Khakimova Y. Experimental and theoretical assessment of the long-term strength of lightweight concrete and its components under compression and tension, taking into account the macrostructure of the material. In E3S Web of Conferences, Vol. 264, p. 02024. (2021).
6. Shermuxamedov, U., Salixanov, S., Shaumarov, S., and Zokirov, F. (2020). Method of selecting optimal parameters of seismic-proof bearing parts of bridges and overpasses on high-speed railway lines. Journal of critical reviews, 7(11), 1578-1585.
7. Zokirov F. Z., Malikov G. B., and Rakhimzhanov Z. K. Calculation of the length of temporary water profiles during foundation installation works. Eurasian Journal of Academic Research, 2(12), 1253-1258. (2022).
8. Adilhodzhayev A., Shaumarov S., Elena S., and Ulugbek S. New method for diagnostic of heat engineering and mechanical properties of cellular concrete. International Journal of Engineering and Advanced Technology, 9(1), 6885-6887. (2019).
9. Ishanovich A. A. et al. Some aspects of the photo-optical method of estimation composition of light concrete //International Journal of Engineering and Advanced Technology. – 2019. – T. 8. – №. 5. – C. 1924-1927.
10. Shermuxamedov U., and Shaumaro S. Impact of configuration errors on the dynamic oscillation absorbers effectiveness of different masses on the seismic resistance of bridges. In E3S Web of Conferences, Vol. 97, p. 03017. (2019).
11. Raupov C., Shermuxamedov U., and Karimova A. Assessment of strength and deformation of lightweight concrete and its components under triaxial compression, taking into account the macrostructure of the material. In E3S Web of Conferences, Vol. 264, p. 02015). (2021).
12. Shaumarov S., Kandakhorov S., and Abduraimov, U. Improving the optimal composition of heat-insulating structural aerated concrete based on industrial waste. In E3S Web of Conferences, Vol. 264, p. 02023. (2021).
13. Liu Y., Wu J., and Chen J. Mechanical properties of a waterproofing adhesive layer used on concrete bridges under heavy traffic and temperature loading. International Journal of Adhesion and Adhesives, 48, 102-109. (2014).
14. Shermuxamedov U., Shaumarov S., and Uzdin A. Use of seismic insulation for seismic protection of railway bridges. In E3S Web of Conferences Vol. 264, p. 02001. (2021).
15. Salixanov S. S. New Type of Road Bridge Riding Cloth Construction Using Self-Tensioning Concrete. International Journal of Advanced Research in Science,

Engineering and Technology, 6(11), 11655-11657. (2019).

16. Wang, W. W., and Dai, J. G. (2013). Self-stressed steel fiber reinforced concrete as negative moment connection for strengthening of multi-span simply-supported girder bridges. Advances in Structural Engineering, 16(6), 1113-1127..
17. Raupov C., and Malikov G. Determination of physical and structural-mechanical characteristics of expanded clay concrete. Science and innovation, 1(A5), 264-275. (2022).
18. Raxmanov, U. S., and Ismailova, G. B. Calculation of seismic resistance of reinforced concrete railway spans without prestressing reinforcement. Journal of Tashkent Institute of Railway Engineers, 16(3), 164-169. (2020).
19. Mardonov, B., An, E., Shojalilov, S., Khakimova, Y., and Ismoilova, G. (2021). Transverse Vibrations of Underground Pipelines with Different Interaction Laws of Pipe with Surrounding Soils. In E3S Web of Conferences (Vol. 264, p. 02035).
20. Adylkhodzhaev, A. I., Shaumarov, S. S., and Muhammadiev, N. R. Analytical and experimental study of the structural organization of heat-insulating and structural building materials for railway buildings and structures. Proceedings of the Petersburg University of Communications, 16(2), 220-229. (2019).
21. Raupov, C., and Malikov, G. Creep in expanded clay concrete at different levels of stress under compression and tension. In E3S Web of Conferences, Vol. 365, p. 02008, (2023).
22. Raupov, C., and Malikov, G. Comparison of microcrack formation boundaries determined by complex of physical methods with long-term strength of expanded clay concrete under different types of stress state. In E3S Web of Conferences, Vol. 365, p. 02023. (2023).