ISSN: 2977-0041

Review Article

Journal of Material Sciences and Engineering Technology

Recessed Reinforced Concrete Structures to Strengthen Weak Foundations

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Received: April 25, 2023; **Accepted:** May 02, 2023; **Published:** May 05, 2023

ABSTRACT

Ensuring reliable operation of high-speed lines is an important geotechnical task. To ensure normalized values of settlement of the roadway in the presence of weak engineering-geological elements in the bases, the issues of increasing their bearing capacity are especially relevant. To do this, modern construction has a number of geotechnical technologies, as a rule, these include buried reinforced concrete structures immersed in the ground. ready-made or manufactured in the ground.

Keywords: High-Speed Highway, Buried Reinforced Concrete Structures, Bored Piles, EDT Electric Discharge Technology

Construction of any objects on weak foundations requires special approaches associated with increasing strength and reducing their deformability. Using modern domestic geotechnical technologies, it is possible to solve the problems of increasing the bearing capacity of weak foundations.

High-speed highways are among the most critical objects, which are subject to the minimum maximum allowable precipitation Su = 15.0 mm. At the same time, their foundations very often contain engineering-geological elements with increased values of deformation characteristics and weak strength properties.

This article considers the case of design strengthening of weak foundations (VSM) in the section Moscow - Nizhny Novgorod.

The projected route of the high-speed highway runs within the Volga-Ural arch.

The investigated construction site belongs to the territories with complex engineering and geological conditions.

During the Quaternary time, different parts of the territory under consideration were in different climatic conditions and were exposed to various physical and geographical processes. Its northern part has repeatedly been subjected to glaciation, and the southern part - to the impact of transgressions of the Caspian Sea. These various conditions left their mark on the nature of the Quaternary cover of the territory. In the northwestern part of it, glacial and water-glacial formations are widely developed, in the middle - alluvial and eluvial-deluvial, and in the southernmost territory - marine firth deposits. Peat, brick clay, sand, sand with interlayers of gravel, loam and clay are found in the thickness of the Quaternary deposits (in the floodplain terraces of the Volga, Sura and Tsivil).

In the regions of the Nizhny Novgorod and Cheboksary Volga regions, the cover deposits are represented by light loams and heavy sandy loams of a characteristic yellowish or brownish-yellow color with clearly pronounced signs of loess (macroporosity, columnar separation, etc.) and subsidence properties. The watering of the rocks of the complex is insignificant and has a sporadic character.

Recent swamp deposits (bIV) are unevenly distributed over the entire study area. In extensive relief depressions confined to river valleys or lowlands in the forest zone, especially large peat bogs-peat basins are formed. Low-lying and high-moor peatlands are found in approximately equal numbers in the territory under consideration. Deposits are represented by peat and peaty soils. The average thickness of swamp deposits is from 2 to 3 m and can reach up to 10 m. In some areas where swamp deposits are developed, swamp waters occur directly from the surface.

In order to select the option of strengthening weak foundations, both sections of the route were considered under which embankments of types Nos. 3 and 4 were designed. The engineering-geological foundations of the embankments are given in tables Nos. incision.

Citation: Sokolov Nikolai Sergeevich. Recessed Reinforced Concrete Structures to Strengthen Weak Foundations. J Mat Sci Eng Technol. 2023. 1(2): 1-4.
DOI: doi.org/10.61440/JMSET.2023.v1.10

Table 1: Physical and mechanical characteristics of foundation soils under type 3 embankment

No n/n	Conventions	IGE name	ρ_n r/m^3	φ_n, deg	C_n kПa	E_0, MПa	K_ϕ, m/ day	EGE thickness, m
1	$11_б2$	Fine sand of medium density, wet, water-saturated	2.0	35.0	—	25.7	3.4	3.0
2	$11_е2$	Sandy loam plastic	1.05	24.0	25.0	25.4	$3*10^{-3}$	2.0
3	$21_з3$	plastic clay	1.76	12.0	38.0	6.0	$1*10^{-5}$	1.0
4	$21_з2H$	Clay semi-hard	1.74	13	46	18	$1*10^{-5}$	2.5
5	$24_ч7$	Dolomite is very (low strength)	2.12	—	—	—	0.005	

Table 2: Physical and mechanical characteristics of base soils under type 4 embankment

No n/n	Conventions	IGE name	ρ_n r/cm^3	φ_n, deg	C_n kПa	E_0, MПa	K_ϕ, m/ day	EGE thickness, m
1	$3_ж4$	Soft-plastic loams with impurities of organic inclusions	1,94	17,0	18,0	11,2	0,05	2,0
2	$20_ж4$	Soft-plastic loam	1,94	4,0	18,0	5,18	$3*10^{-4}$	1,0
3	$20_б2$	Fine sand of medium density, water-saturated	2,00	36,0	4,0	37,0	4,0	2,5
4	$20_з1H$	Clay hard	1,95	16	66	39,0	$1*10^{-5}$	

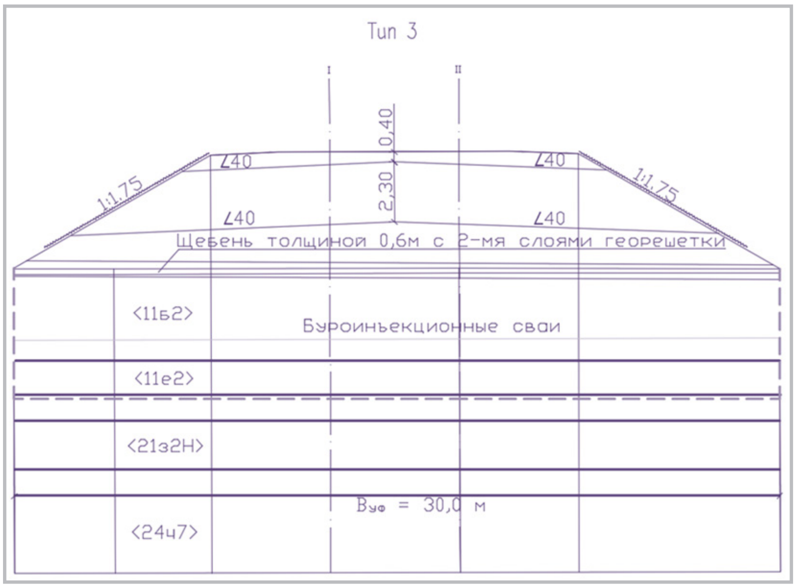


Figure 1: Section of the roadway with a vertical reference to the engineering-geological section

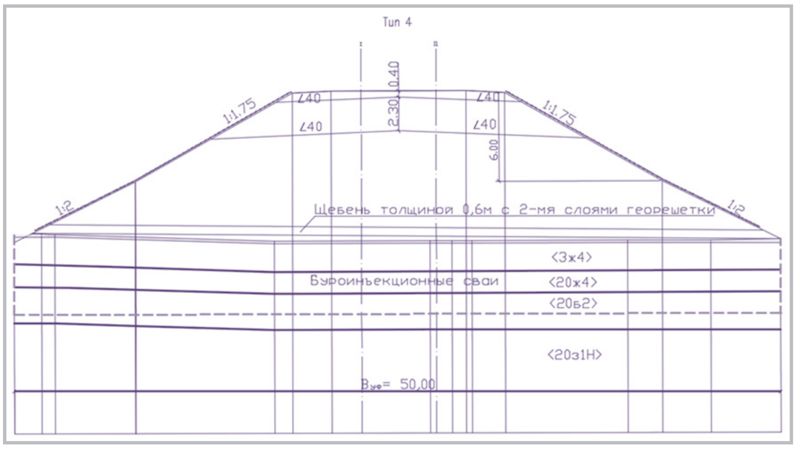


Figure 2: Cross-section of a type 4 roadbed with a vertical reference to the engineering-geological section

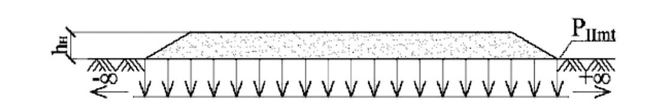
The algorithm for determining the settlement of embankments of high-speed highways in the presence of weak bases in the bases is given below.

1. Determination of loads from the rolling stock of supporting structures, from the inter-track, the body of the embankment at the level of its sole;
2. Determination of stabilized settlement by one of the methods: 1) layer-by-layer summation method, 2) linearly deformable layer method of finite thickness, 3) equivalent layer method;
3. When the calculated settlement of the bases is higher than the maximum allowable value, the depth of the reinforced part of the base is assigned;
4. The type of buried reinforced concrete structure is assigned;
5. The average pressure P IImt along the base of the conditional foundation and the value of the stabilized settlement are determined by one of the methods (see pos. 2);
6. The stabilization time of the base deformations is determined for the case of loading the base surface with a solid one (intensity of a uniformly distributed load P IImt;

Tables Nos. 3 and 4 below show geotechnical calculations of stabilized deformations of bases of types Nos. 3 and 4, and Table No. 5 shows an algorithm for determining the stabilized settlement of the same bases by the equivalent layer method (MES).

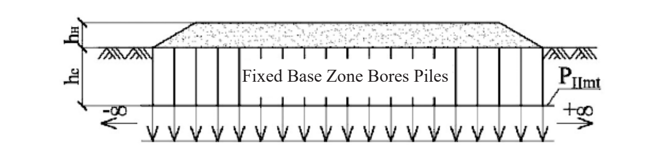
The need to determine the settlement of the MES lies in the fact that when the normalized settlement exceeds the maximum allowable value, the time is calculated [1-12].

Table 3

No	Settlement Calculation Method	Calculation Formula Precipitation	Value Stabilized Draft, mm
1	2	3	4
			
1	Layered Summation Method	$S=0,8\Sigma[(\sigma_{zpi}.h_i)/E_{0i}]$	85,0 / 73,0
2	Linear Layer Deformable Method of Finite Thickness	$S=(P.b_{kc}/K_m).\Sigma[(k_i-k_{i-1})/E_{0i}]$	78,0 / 73,0
3	Equivalent Layer Method	$S=h_3.m_{vm}.P_0$	69,5 / 58,0

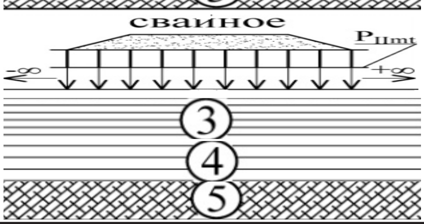
Notes: values above the line for embankment type #3; values below the line for embankment type No. 1

Table 4

No	Settlement Calculation Method	Calculation Formula Precipitation	Value Stabilized Draft, mm
1	2	3	4
			
1	Layered Summation Method	$S=0,8\Sigma[(\sigma_{zpi}.h_i)/E_{0i}]$	14,8 / 13,8
2	Linear Layer Deformable Method of Finite Thickness	$S=(P.b_{kc}/K_m).\Sigma[(k_i-k_{i-1})/E_{0i}]$	13,0 / 14,9
3	Equivalent Layer Method	$S=h_3.m_{vm}.P_0$	14,5 / 12,8

Notes: values above the line for embankment type #3; values below the line for embankment type No. 4

Table 5: Algorithm for determining settlement by the equivalent layer method

No	Type of Embankment	Base Type	Name Soil	H_i, m	E_{0ed}, МПа	m_v, МПа	$K_ф$, m/day	P_{IImt}, кПа	h_0, М	S, MM
1	2	3	4	5	6	7	8	9	10	11
1	No 3									
			Sand	3,5	7,3	0,101	3,4			
			Sandy loam	1,5	6,4	0.116	3.10^{-3}			
			Clay	1,0	1,3	0,300	1.10^{-3}			
			Clay	2,0	4,0	0,100	1.10^{-3}			
			Dolomite					1200	8,0	69,5
										
			Clay	1,0	1,3	0,300	1.10^{-3}			
			Clay	2,0	4,0	0,100	1.10^{-3}			
			Dolomite					300	3,0	14,5

2	No 4									
			loam	2,0	3,2	0,194	0,05			
			loam	2,0	3,2	0,413	3.10^{-4}			
			Sand	3,0	10,6	0,070	4,0			
			Clay		6,5	0,062	1.10^{-5}	220	15,0	58,0
										
			Sand	1,0	10,6	0,070	4,0			
			Clay		6,5	0,062	1.10^{-5}	400	15,0	12,8

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