ISSN: 2643-6876
Current Trends in
Civil & Structural Engineering
DOI: 10.33552/CTCSE.2024.11.000751
Iris Publishers

Review Article


# Geotechnical Practice of Construction on Unstable Slopes

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**Received Date:** May 01, 2024

**Published Date:** May 20, 2024

## Abstract

The construction of facilities for various purposes in rough areas in cramped conditions of urban development is the main problem for builders related to the solution of geotechnical problems of ensuring both the slope itself and buildings and structures of the surrounding buildings in the zone of geotechnical influence. Questions arise with the need to develop buried retention structures. The article discusses a case from the geotechnical practice of installing retention structures with the use of bored piles with diameters of 600 mm and 800 mm and ground anchors arranged using electric discharge technology (ERT anchors).

**Keywords:** Geotechnical construction; electro hydraulics; monolithic reinforced concrete grillage; bored piles; especially cramped geotechnical conditions; soil anchors of ERT

## Introduction

Construction of buried objects in particularly cramped conditions on unstable slopes from geotechnical engineers [1-7] of a specific approach, who must show ingenuity and ingenuity in the use of modern geotechnical technologies that ensure the safe operation of existing buildings [8-10] both during construction and during the operation of newly erected buildings and structures [11-15]. The initial data for the development of the project for the installation of retaining structures were:

a. Project documentation "Integrated development of the residential complex "Dubrava Park", the city of Cheboksary" (financing the costs of engineering networks and communications for water supply, sewerage, electricity and heat supply, gas supply, roads for the complex development of the residential complex "Dubrava Park", the city of Cheboksary). Street and road networks of the Dubrava Park micro district, Cheboksary" code of the Group of Companies No. 24/10-2022, made by LLC "CITYSTREETPROJECT" in 2023;

b. Technical report on the results of engineering and geological surveys at the facility: "Land plot with cadastral number 21:01:010902:156, located at: Chuvash Republic - Chuvashia, Cheboksary urban district, Cheboksary", made by GIZ LLC in 2021, code 10309-IGI;

c. Determination of the stability of the retaining walls of the complex development of the Dubrava Park micro district in Cheboksary. Technical report on the results of engineering and geological surveys for the preparation of project documentation, code 5570-IGI, performed by CJSC "Institute "Chuvashgiprovodkhoz" in 2023;

d. Technical report "Examination of the technical condition of the building structures of the garage complex and residential building No. 25 k.1 at the address A. Mittov Boulevard, falling into the zone of influence of the new construction of the object "Residential complex "Dubrava", code TO-09/23, performed by LLC "IC "EXPERT" in 2023 [16-19].

Geomorphologically, three areas have been identified on the construction site: 1) the marginal part of the drive-dividing plateau (types AI and AII) with elevations from 130.0 to 140.0 m, with a slight slope (up to 4-5º) to the SE, to the Sugutka valley, and it consists of up to six geomorphological elements: at least three fragments of leveling surfaces with accumulative (AI) and denudation (AII) areas and two buried gullies with ravines and drainage hollows within them; 2) floodplain accumulative (PT) terrace with a width of 2.0-3.0 m to 15.0-20.0 m and a narrow channel of the Sugutka River with elevations from 104 m to 98 m, the average slope of the floodplain is 0.006; 3) landslide (BIV-BV) left slope of the valley between the plateau and the floodplain of the Sugutka River. It is gently sloping, wavy-bumpy with many winding hollows of runoff on the borders of more than two dozen local landslides of flow and slippage with head blocks Vr, Sb.

Within the erosion cut marks, the bedrock is represented by essentially terrigenous (argillitized clays and sands) rocks of the Vyatka and Severodvinsk horizons of the Tatar stage of the Upper Permian (P3t) with a marking pack of marls "Zh" between them at elevations of 120.0-125.0 m (the South East area) and 114.0-11.0 m (the SevOS site). Their subhorizontal occurrence without signs of deformation indicates the general stability of slopes with a steepness of less than 10º and a height of up to 36 m. Most of the territory is covered from the surface with a soil and vegetation layer (PRS) with a thickness of 0.2-0.5 m. on the slope there are the same rocks, but fragments of the 1st (Ostashkov-aIII2) and 3rd (Moscow-aII2) alluvial-periglacial terraces deformed by landslides; on the floodplain there are alluvial loams (aIV) that are silty to varying degrees. Of all the soils of the Quaternary age, the greatest role in the stability of the massif is played by the soils EWG-1 (IGE Nos. 3, 4) and EWG-2 (IGE Nos. 5, 6).

Groundwater is represented by four aquifers (aquifers). The first aquifer has a high-water regime within the built-up part of the plateau. The second aquifer is an interstitial aquifer in a pack of marls of the bedrock massif in the range of 121.0-124.0 m in the southern part of the massif and 114.0-110.0 m in the northern part. The third aquifer is a slope complex that includes the PV of all three floodplain and four or five landslide terraces with a total thickness of up to 10.0 m on the aquiclude represented by the surface of the Tatar bedrock. The 4th VG is represented by the PV of the floodplain terrace of the Sugutka River, which is closely connected with channel waters. Of these, the 2nd and 2nd VG play the greatest role in the stability of the slopes. In terms of chemical composition, PVs are fresh, bicarbonate, calcium, non-aggressive to concrete of the W4 grade. For approximate calculations, the following Kf values are recommended: for loess loams – 0.64 m/day, for sandy loams (dQII) – 1.05 m/day, for fractured bedrock clays (P3t) – 0.71 m/day.

Structural solutions of buried reinforced concrete retaining structures, substantiated on the basis of geotechnical stability calculations taking into account design loads, are:

a) The upper retaining wall (buried reinforced concrete retaining structure) is a flexible anchored wall. The structure of the fence is made of bored piles, fixed from horizontal displacement by ground anchors, arranged using electric discharge technology (ERT anchors). At the top, the piles are united by a monolithic reinforced concrete binding beam. The cladding of the vertical surfaces of the buried structure is made in a monolithic reinforced concrete design. Bored piles are designed with diameters of 620 mm and 800 mm, lengths of 20.0 m, 18.0 m, 17.0 m and 12.0 m. The length of the root of the ERT ground anchors is 10.0 m. Vertical drainage is provided behind the lining in the interpile space, which ensures the drainage of groundwater accumulated behind the wall into the drainage collector located along the retaining wall. Surface water drainage is carried out through reinforced concrete flumes located along the strapping beam.

b) The lower retaining wall (buried reinforced concrete retaining structure) is a complex consisting of anchor structures, an angle reinforced concrete wall and a pile foundation. Fencing piles are bored with a diameter of 620 mm, 13.0 m and 19.0 m long, are made under the protection of casing pipes. Ground anchors (ERT anchors) with a diameter of 150 mm (diameter according to the drilling tool), root length - 10.0 m, are made using electric discharge technology and prestressed For Reservoir drainage is provided to ensure the passage of groundwater at the level of the slab part (only in areas with a pile foundation). A drainage collector ensures the passage of groundwater from the level of the wall part of the support. Surface water drainage is carried out through reinforced concrete flumes located along the retaining wall.

Calculations on the strength of the base of retaining walls were carried out in the Geo Wall software package based on the Blum-Lohmeyer method (the "elastic line" method) and the Jacobi method (iterative process).

Figures 1-5 shows an engineering-geological section under the road with vertical referencing of buried retaining structures, plans of soil anchors of the upper a) and lower b) chords of the ground anchors, attachment points of the soil anchors of the upper and lower chords to the monolithic reinforced concrete corner retaining wall, the attachment point of bored piles to the monolithic reinforced concrete corner retaining wall, a fragment of the monolithic installation of the monolithic reinforced concrete fence with an indication of the attachment point of the ground anchor ERT.

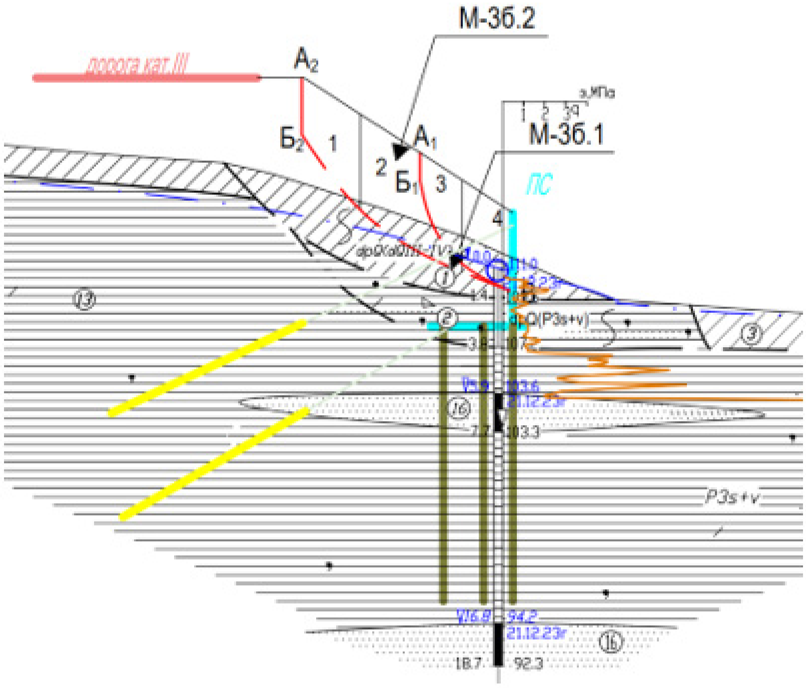
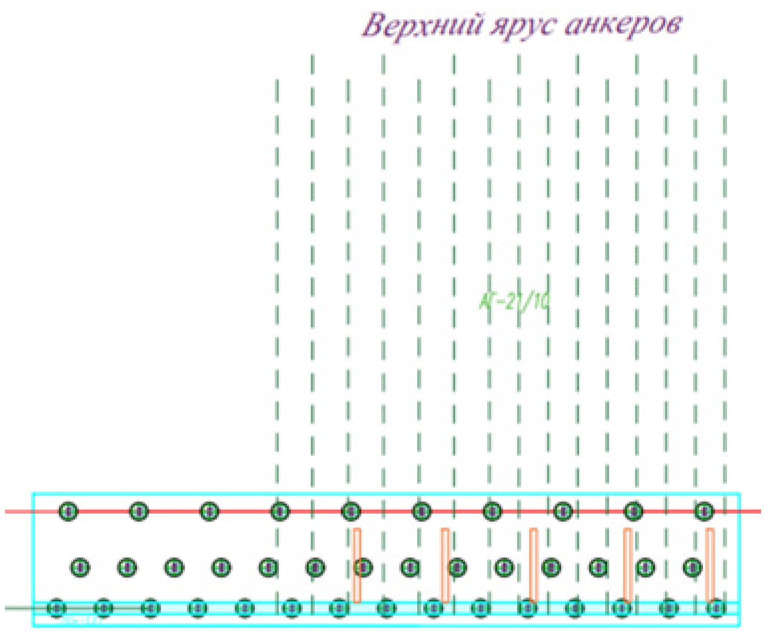



**Figure 1:** Geotechnical section under the road with vertical referencing of buried retention structures.




(a)

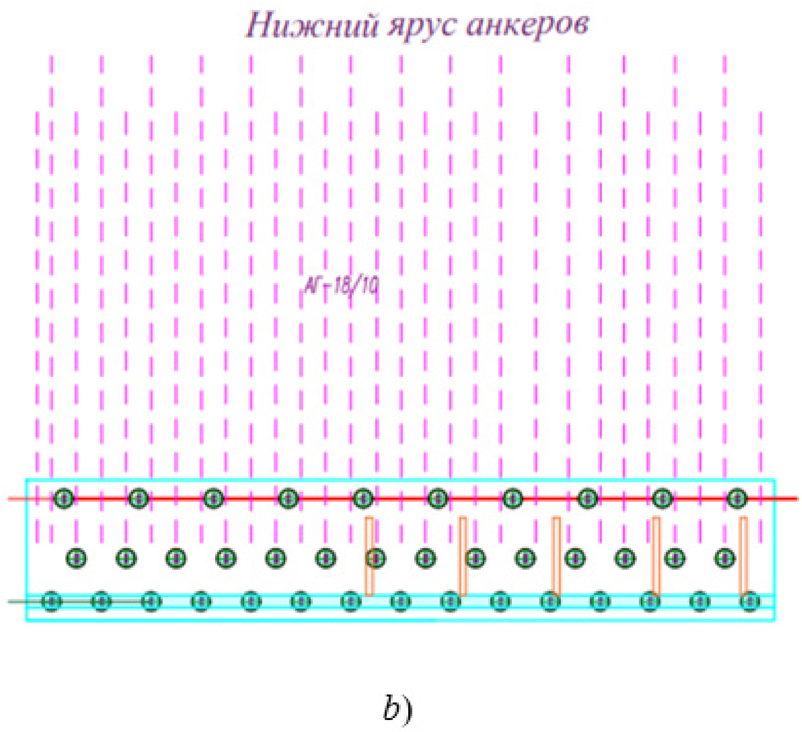



**Figure 2:** Plans of ground anchors of upper a) and lower b) chords of ground anchors.

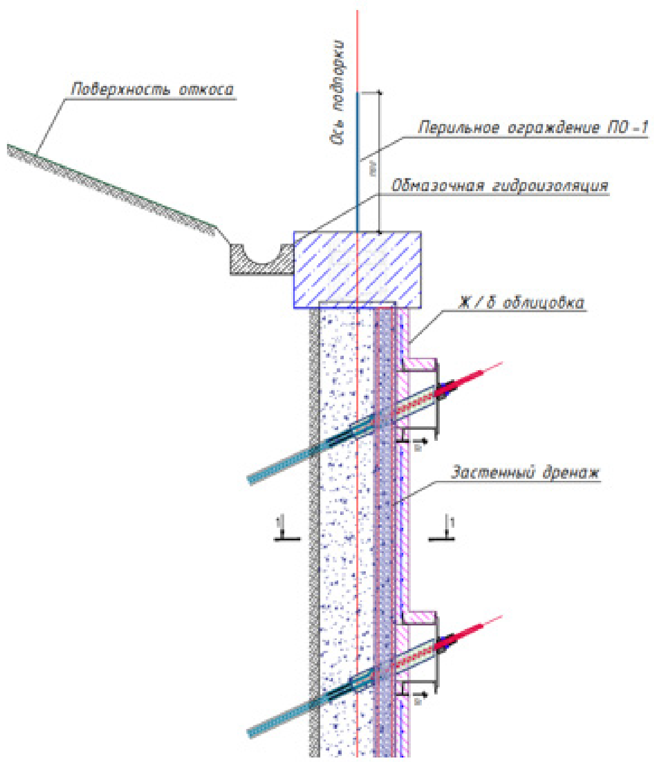



**Figure 3:** Attachment points of soil anchors of the upper and lower chords to the monolithic reinforced concrete corner retaining wall.

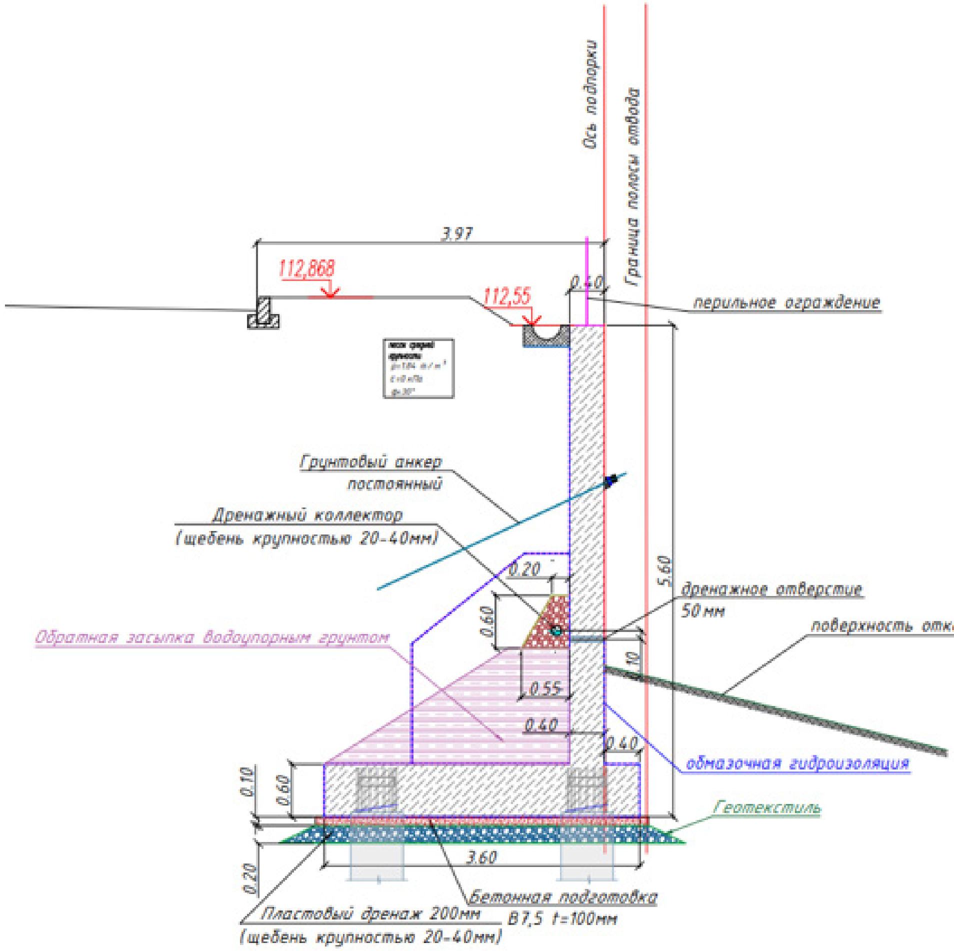



**Figure 4:** Attachment point for bored piles to a monolithic reinforced concrete corner retaining wall.

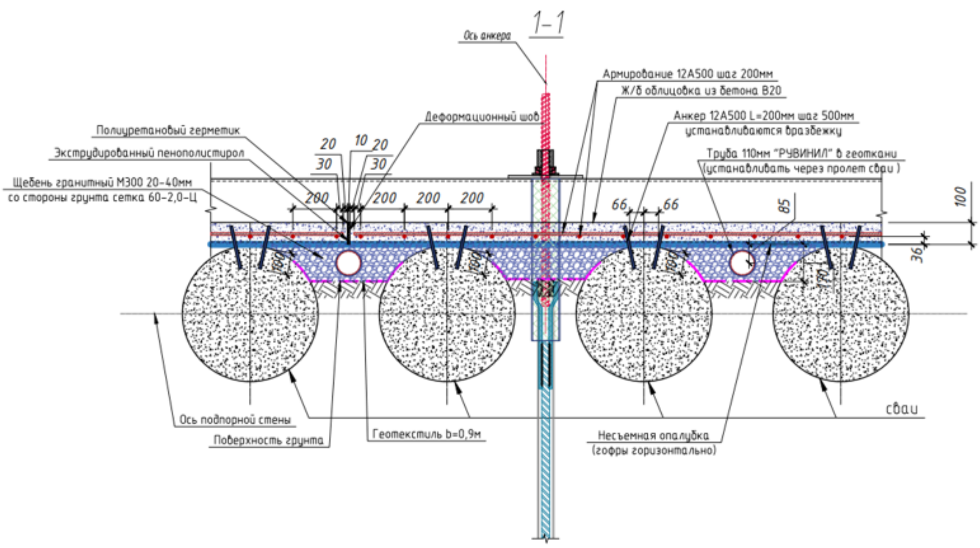



**Figure 5:** A fragment of a monolithic reinforced concrete fence with an indication of the attachment point of the soil anchor ERT.

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