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Damage Forms and Destabilization Mechanism of Red Sandstone Roadbed Slopes

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Abstract

Red sandstone is composed of sedimentary rocks such as mudstone, muddy sandstone, sandstone, sandy mudstone, and shale, which appear red, brown, or dark red due to the abundance of iron oxides. Terrestrial depositional environments that are widely distributed globally in arid and semi-arid regions are mainly concentrated in sedimentary basins since the Mesozoic era, with China, the United States, India, Australia and the Middle East being the main distribution areas. In China, red sandstone occupies 8.61% of the total land area and is concentrated in the southeast, southwest and northwest regions. Red sandstone has strong weathering disintegration and water softening properties, and the lubrication between particles and softening of minerals after immersion in water will lead to deformation and destabilization of the rock body; Water infiltration into the pore fissures after adsorption of water film thickening, dissolution of cement, triggering particle disintegration and disintegration, easy to cause settlement of the roadbed and slope instability.

Keywords: Red Sandstone, Slope Failure, Destabilization Mechanism, Water-Rock Interaction, Engineering Control

Анотація

Червоний пісковик складається з осадових порід, таких як аргіліт, мулистий пісковик, пісковик, піщаний аргіліт і сланець, які виглядають червоними, коричневими або темно-червоними через велику кількість оксидів заліза. Наземні осадові породи, які широко поширені в посушливих і напівпосушливих регіонах, в основному сконцентровані в осадових басейнах, починаючи з мезозойської ери, причому основними районами їх поширення є Китай, США, Індія, Австралія і Близький Схід. У Китаї червоний пісковик займає 8,61% загальної площі суші і зосереджений у південно-східних, південно-західних і північно-західних регіонах. Червоний пісковик має сильні властивості розпаду при вивітрюванні та пом'якшення води, а змащення між частинками та розм'якшення мінералів після занурення у воду призведе до деформації та дестабілізації гірського масиву; Просочування води в порові тріщини після адсорбції потовщення водяної плівки, розчинення цементу, що викликає розпад та розпад частинок, легко викликає осідання дорожнього полотна та нестабільність схилу.

Ключові слова: Червоний пісковик, зсув схилу, механізм дестабілізації, взаємодія вода-порода, інженерний контроль

Introduction

The structure of red sandstone is divided into mud-like cemented structure and granular clastic structure, and the strength is significantly affected by the degree of weathering and cementing material. They can be divided into two categories according to the petrological classification: claystones (mudstones, sandy mudstones, shales, etc.) and clastic rocks (conglomerates, sandstones, siltstones, etc.). The engineering properties of clay rock types are determined by hydrophilic minerals such as montmorillonite (3%-10%) and illite (5%-30%), which are poorly water-stable and prone to disintegration and softening, with clay minerals accounting for 15%-50% of the total; Iron oxides in clastic rock types are mostly leached and cemented in a variety of ways, including iron carbonate, basal and porous, with iron usually not affecting engineering properties. The red sandstone is susceptible to disintegration and sedimentation due to dry and wet cycles after exposure, and the particle gradation and physico-mechanical properties change dynamically with time. Yu, C., et al. (2019) revealed experimentally that the peak strength and modulus of elasticity of red sandstone decreased not only with the increase of water content but also with the increase of soaking time.

Results of the study

The engineering geological characteristics of the red sandstone include: the distribution of the rock body is significantly uneven, containing soft and weak interlayers or muddy interlayers; the slope is broken and permeable, with multilayered soft and hard interlayer structure. Weathering depth is large (can exceed 10m, more drastic when siltstone and mudstone are interbedded), synergized by water and temperature, and influenced by rock composition, tectonic strength and climatic conditions. Zhao, K., et al. (2021) found that red sandstone specimens in the saturated state formed shear macroscopic fracture surfaces, whereas red sandstone specimens in the natural state formed a damage pattern in which shear damage and cleavage damage coexisted. The clayey red sandstone is easily disintegrated and softened, and gradually breaks up into mud or slag after wet and dry cycles; The clastic rock type has a high compressive strength, but still disintegrates after prolonged wet and dry cycling (about 8 times/60 days) and eventually stabilizes; The granular debris structure is stabilized by the disintegration of massive particles, and very few particles with a particle size <0.5 mm are produced in the form of massive disintegration. These characteristics lead to the red sandstone project is prone to cause roadbed settlement, slope slippage and other diseases, need to be targeted prevention and control. Liu, Q., et al. (2019) found that some minerals (microplagioclase feldspar, sodium feldspar, and calcite) in red sandstone decompose when heated to 500 °C.

Common forms of damage to red sandstone roadbed slopes. The stability of red sandstone slopes, which are rocky slopes, is affected by weathering of the rock, rainwater infiltration, and controlled by the structural surface of the rock . Usually, the most intense weathering is at the foot of the slope, so the damage of red sandstone slopes is often a combination of weathering spalling and destabilization damage of the structural surface. The common forms of damage to red sandstone slopes are: sloughing, weathering and spalling, wedge damage, avalanches and landslides along the layers. Niu, C., et al. (2021) through freeze-thaw cycle tests found that, with the increase of the number of freeze-thaw cycles and the peripheral pressure, the compression of the red sandstone is increasing, the peak strain is gradually increasing, the plastic yield section is becoming more and more obvious, the rate of post-peak stress reduction is slowing down, and the damage mode is changing from brittle to ductile; The modulus of elasticity, peak stress and residual strength increased with increasing perimeter pressure and decreased with increasing number of freeze-thaw cycles.

Slip slump, is the slope by rainfall, soil saturated with water content, the slope along the longitudinal cracking, part of the soil body and the parent body to disengage and along a certain sliding line occurs sliding. When there is heavy or continuous rainfall, it is prone to outbreaks of slipping and collapsing disasters. Conditions under which sloughing disease occurs: large catchment areas, such as gently sloping lots with concave catchment conditions; There is an accumulation of thick layers of loose sandy clay with gravel; hillside vegetation is locally damaged, surface is uneven, and drainage is poor.

Weathering spalling manifestations are: local collapse, fragmentation spalling, fragmentation spalling and fragmentation spalling, by the rain erosion is prone to produce gullies. Local collapse is often developed in the local slope containing more sandstone, tectonic joints and weathering fissures and other favorable cuts, collapse body volume is generally 1 ~ 3m³ or so; Tectonic joints are more densely developed, the temperature difference is more likely to occur at the fragmentation of spalling, weathering quite heavy belt of siltstone and mudstone, often weathered into 2 ~ 3cm of small fragments, with the intensification of the degree of weathering and the expansion of weathering cracks, in the external forces that is, collapse, usually only occurs locally on the slope surface, the collapse of the amount is not large; Fragmentary spalling, usually by strong sunlight and large temperature differences in the mudstone, making the surface of the formation of small fragments of about 0.3 to 0.6 cm thick, in the rain and gravity and other effects of spalling accumulation at the foot of the slope, small fragments of sharp edges, hardness, close to the original rock; Fractured granular spalling is often distributed in the more humid, temperature difference is not too big area, by physical weathering of mudstone, the surface gradually formed about 0.2 ~ 0.5cm size particles, in gravity, rain and other external forces, the accumulation of the foot of the slope. Niu, C., et al. (2021) found that red sandstone has three pore types and is susceptible to freeze-thaw weathering.

Wedge slope badness, in general, is controlled by the relationship of the level to the tectonic structural surface. When the upper part of the slip surface is a tectonic surface and the lower part is a level, it will slide along the composite slip surface of the tectonic surface and the level; Wedge landslides tend to occur along the structural face of a structure when the structural face has a broken mud layer and filled soils.

Landslide damage, potential collapse points often exist when slopes are too steep, when stratified joint-developed rock bodies are acted upon by rain, or when soft mudstone and siltstone are distributed in the lower layers and hard, thickly bedded sandstone in the upper layers.

Shunyata landslide. Under tectonic action, the red sandstone mountains mostly form gently dipping rock bodies with dips of 10° to 25°. When the slope angle rock is greater than the layer inclination, and the slope direction is the same as the inclination of the rock layer, it is possible to develop a landslide along the layer, especially when the red sandstone is hard rock and soft rock alternating into a layered multi-structured rock body, and excavation along the direction of the rock layer, it is often prone to landslides.

Destabilization and damage mechanism of red sandstone roadbed slopes. Due to the special physical properties and tectonic characteristics that red sandstone has, the mechanism that leads to the destabilization damage of red sandstone slopes is both similar to the same type of slope destabilization damage and the existence of special development conditions. The following four conditions should be met at the same time if the landslide is to follow the layer: Angle of internal friction φ < rock dip α; Rock dip α < slope angle β; Both surfaces disengaged; Rock outcrop.

Sliding occurs along soft, muddy interlayers. The internal friction angle φ of the weak interlayer is generally 19°~30°, and the cohesion c is about 0.04~0.09 kg/cm^2. The weak interlayer of red sandstone will cause a significant decrease in the skidding resistance due to mudding, and its internal friction angle can sometimes be reduced to 8°~11°. The mudded interlayers in red sandstone tend to be the weakest and longer-extending possible sliding surfaces, so that destabilizing damage to red sandstone slopes occurs primarily along the weak mudded interlayers.

Weathering causes a reduction in the shear strength of the slip surface and contributes to slope instability. The red sandstone, with clay minerals as the main cement, weathered rapidly after exposure to atmospheric conditions and softened in contact with water, leading to a rapid decrease in the strength of the rock mass, and a corresponding decrease in the interlayer cohesion and friction, which resulted in a consequent decrease in the shear strength. The weathering depth of the red sandstone is often large when it is subjected to strong weathering, generally more than 10 m. In addition, because many tectonic joints have been opened, the development of mud sandwich is strong, and when subjected to prolonged heavy rainfall, the rainwater seeps into the slope, and then seeps out of the slope along the mud sandwich. Statistical results show that for the parts of the rock formation with inclination greater than 15°, most of the slides will be destabilized after the excavation exposure. There are many slopes that are deformed and destabilized by fissure water pressure triggered during the rainy season after several years of exposure, when the strength of the rock body has decreased due to weathering. As a result, the red sandstone under the action of strong light and rainfall after a number of wet and dry alternation, when the strength of the sliding surface of the siltation of the interlayer reduces to a certain value, then the landslide will be generated.

Rainfall is a key trigger for landslides in red sandstone. Landslides on red sandstone slopes occur mostly during the rainy season. The generation of landslides is closely related to the intensity and amount of rainfall in the year, as well as to the lithology of the strata, topography and geological formations. Heavy as well as sustained rainfall can significantly reduce the shear strength of the slip surface. In addition, due to the development of joints, laminations and fissures in the red sandstone, when rainwater infiltrates into the fissures, it increases the sliding force sliding down the slope and also reduces the anti-slip abrasion resistance, and the two together result in a reduction of the slope stability coefficient.

Conclusion

This paper systematically introduces the petrological classification, engineering geological characteristics and slope damage forms of red sandstone, reveals its destabilization mechanism as the core of the composite effect induced by weak intercalation sedimentation, water-rock interaction and rainfall, and elucidates the dynamic process of particle disintegration and shear strength attenuation caused by dry and wet cycles, as well as the controlling effect of the inclination angle of the rock stratum and the geometric conditions of the slope on the downstream landslides, and points out that the destruction of the slope of red sandstone roadbed is the result of the synergistic effect of weathering and spalling, structural surface destabilization and seepage force, which provides geological basis and theoretical support for the prevention and control of engineering diseases in red sandstone area, and emphasizes the need to combine with comprehensive measures such as drainage optimization, reinforcement of interlayer and weathering protection in order to improve the stability of the project.

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