Analysis of major engineering problems in Red bed region of southwest China

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Abstract

Red bed in China mainly refers to continental sedimentary strata such as lake-river alternating or talus facies in Jurassic, Cretaceous and Cenozoic tertiary system. The red bed in Southwest China mainly is detrital deposit stratum in continental sedimentation; the lithological characters contain sandstone, mudstone, siltstone and shale. As the typical stratum easy to trigger landslide, detrital deposit stratum carries special engineering properties such as strong hydrophilia, easy to be softened in water, easy to disintegrate out of water and low strength. Considering that, the geological disasters including landslide and collapse are serious in red bed region in Southwest China, which influenced engineering safety and economic benefits; based on existing data and information, and aimed at the special engineering property in red bed in Southwest China, this paper summarized the major problems in engineering in red bed region in Southwest China.

Keywords

Red Bed; Characteristics; Engineering problems;China.

1. Introduction

Extensively distributed in Southwest and Northwest China with an area of $26.37 \times 10^4 km^2$, red bed is the detrital deposit stratum formed in Cenozoic arid climate condition; it takes red as dominant tone; sandstone, mudstone, siltstone and shale as ingredients. Southwest, central and marginal areas of Sichuan Basin, north of Guizhou, west of Guizhou, central Yuanan and north Yunan in China all contain red bed, where central and marginal areas of Sichuan Basin cover the largest area of red bed with $16.5 \times 10^4 km^2$. Since red bed mostly is the inter-bedding of sandstone, siltstone and mudstone, the binding force among stratums is poor with weak strength, which is likely to trigger diastrophism along stratum; that is to say, red bed region is prone to cause various geological disasters.

Red bed is detrital deposit stratum, where the mineral compositions mainly are clay mineral and fragmentary materials, so the ancient sedimentary basin and sediment provenances accepting sedimentat are necessary. However, sedimentary basins mostly are inland basins and there are few shore deposit and marine sediment; sediment provenances indicate that, the surrounding mountains provide abundant rock weathering substances. Meanwhile, under the drought and hot paleoclimate environment, due to rock strong weathering and oxidation, bedrock provides sediment provenances and forms red appearance under oxidation; it then sediments and solidifies into rock to form red bed.

The mineral compositions of red beds mainly are clay mineral and fragmentary materials; the fragments generally consist of rock weather substance provided by mountains around; rock fragments mainly are quartz and some feldspar; cements mainly are mud and sand; chemical cements mainly are siliceous, calcium and irony substances. The red bed in Southwest China mainly is sandstone and

mudstone, where sandstone mostly are carbonate cements full of calcium; mudstone is sandstone containing calcium, and it usually contains gypsum in nervations, laminations and plaques.

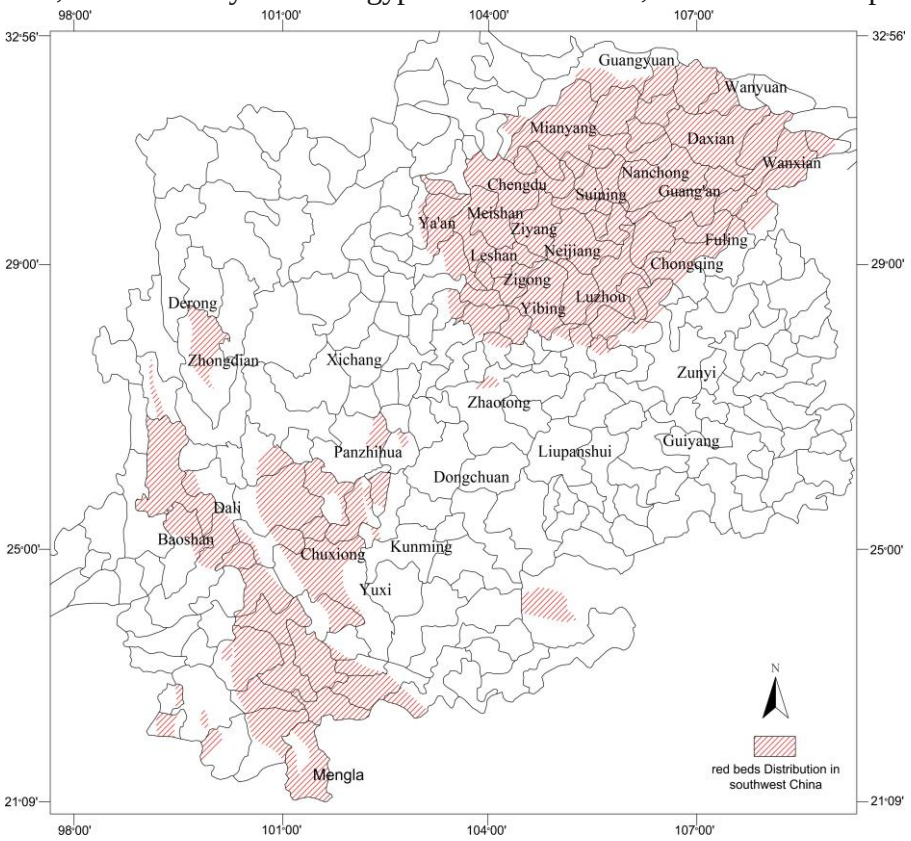

Fig.1 Distribution of red bed in southwest China

2. Main features of the red bed

2.1 Geomorphological features

The major geomorphic types developing red bed in China are plateau, mountain land, hill and plain. With respect to the most representative approximately level red bed distributed in Southwest China, it appears in low mountain and hill with less relative height difference; the landform is mainly controlled by lithology, where parts with exposed sandstone constitute peak of low maintain and hill, which often manifests as table mountain and hill; for the districts in gentle structure and with more exposure of mudstone, it presents as shallow or gentle hill.

Table 1. The distribution characteristics and formation backgrounds of red bed in China

distribution area	Southwest China	Northwest China	Middle south and Southeast China	Other areas
distribution range	Sichuan Basin, Central and Western Yunnan	Ordos Basin, Zhungeer Basin, Qaidam Basin and Tarim Basin	Jianghan Basin, Hengyang Basin, and Yongkang Basin	Shandong, Henan and other parts of the region
Stratigraphic age	Jurassic, Cretaceous	Upper Jurassic, Early Cretaceous, Tertiary	Cretaceous,Early Tertiary	Jurassic, Cretaceous, Tertiary
Background of the formation	Rivers and lakes deposits	Rivers and lakes deposits and foothills sediments	The rivers and lakes of the mountain basins and the foothills sediments	The rivers and lakes of the mountain basins and the foothills sediments

2.2 Hydrogeological characteristics

The red bed region in Southwest China is the typical continental sedimentation. Due to the influences of formation lithology, structure and rainfall, the underground water is in scarcity and watery richness is poor; so the water resource is in shortage. However, in red bed hilly ground in Southwest China, there is still relatively abundant water-bearing structure in rock shallow weathering zone. The water volume in weathering zone generally is small within 100t/d; but the water volume in structural part is larger; particularly in syncline basin and anticline end, the water volume mostly is within 200t/d.

The groundwater in red bed region in Southwest China carries the law of vertical and horizontal distribution. Vertically, superficial parts universally contain fresh water, and mineralization of groundwater increases with depth, which gradually transits from superficial fresh water to brackish water, salt water, saline water and bittern water; horizontally, mineralization of groundwater increases from all round to center of basin, while water quality declines, and fresh water-salt water interface deepens first and then develops from deep to shallow.

2.3 Engineering Properties

Red bed is both a complex mechanical media and special ground. The mechanical strength of red bed depends on lithology; that is to say, in the same lithology, the strength changes dramatically with mineral compositions and contents, cementation degrees, and rates of decay. The mineral compositions of red bed mainly are clay mineral and fragmentary materials; in clay mineral, illite is a strong hydrophilic mineral, so the water character of rock in red bed region presents strong hydrophilia, easy to be softened in water, easy to disintegrate out of water and low strength; meanwhile, it softens and generates plastic deformation under the action of water, which influences the deformation and strength characteristics of rock.

3. Major Engineering Problems Caused by Red Bed Region in Southwest China

3.1 Foundation problem

The soft soil foundation in red bed region contains features of high compressibility, large settlement, low bearing capacity and poor drainage consolidation stability. The soft soil in red bed region in Southwest China mainly is sand and clay particles, which is easily to flow under water stream. Since soft soil covers certain clay mineral, it is likely to generate hydration and swelling in water, while shrink after dehydration. The repeated actions will disintegrate soil mass. When being used as engineering soil, the red bed soft soil is prone to form engineering problems due to poor stability and low bearing capacity.

Partial buildings in red bed region in Southwest China take bed rock as the fundamental bearing stratum; the soil layer is used as bearing stratum only when sand and pebble beds are thicker, or house load is smaller and bed rock burial depth is high. Naturally, the higher the water content in same ground, the weaker the mechanical strength will be. Besides, ground water content is closely related to underground water, where underground water triggers erosion, hydrolysis and lubrication effect within certain scope through permeation, so as to soften soil, lower ground strength, weaken soil drainage consolidation, and reduce bearing capacity of foundation.

3.2 Fresh Water-Salt Water Mixing Caused by Water Exploration in Red Bed

The water conservation in red bed is poor, so instead of permeating into underground to form ugroundwater, atmospheric precipitation runs off by feeding into rivers in shallow ground, which caused limited groundwater storage in red bed region. Brackish water and salt water are universal under the upper fresh water reservoir in red bed region in Southwest China. The formation of brackish water and salt water is closely related to the soluble salt contained in lake-river facies sand mudstone

settled in hot climate; meanwhile, it also is the product of slow groundwater flow alternation as well as change of water quality.

In the water-bearing stratum of red bed region in Southwest China, when containing salt deposition, difficulty in groundwater discharge, or the fresh water-salt water interface is buried shallow, the drilling and dewatering are likely to make substratum bittern mix with shallow water. For this reason, water exploration in red bed must combine with chemical horizontal and vertical distribution law of red bed underground water, lithology of water bearing bed, landform, and relationship between buried condition and runoff condition. In addition, it is necessary to find out fresh water-salt water interface, and water quality type as well as water environment situations of watery units in different categories.

3.3 Slope Problem

The slope problems in red bed region in Southwest China mainly include collapse and landslide. The lithology of rock in red bed region in Southwest China carries soft and weak interphase laminated structure. Because the rock in red bed region has special engineering property, where dry and wet climate changes are frequent, so that the rock-soil body absorbs and losses water repeatedly, and generate swelling as well as collapse. This action causes weathering and peeling of rock-soil body on surface, which reduced rock strength and slope stability with forming serious potential engineering risk. The landslide occurred in red bed region is closely related to rainfall. The precipitation in red bed region in Southwest China is so abundant that, the annual rainfall in most regions is above 1000mm. Due to the excellent permeability of sandstone in red bed, rainfall permeates along pore or fissure, which forms perched groundwater when encountering mudstone will low porosity and poor permeability with forming waterproof baffle. This will increase pore water pressure, make weak intercalated layer in red bed or weathered layer dislocate fracture zone to form muddy intercalation, and increase the possibility that sliding surface slides along weak intercalated layer, which is likely to generate shallow landslide.

3.4 Stability of Surrounding Rock and Water Bursting

The lithology of rock in red bed region in Southwest China is weak, where the joint fissure is in fracture development, rock mass is serious and rock strength is poor. Meanwhile, the exits of shallow-buried tunnel and mountain tunnel usually trigger top arch collapse and cause deformation of mountain outside the hole. During the construction in underground cavern, it is likely to trigger collapse of tunnel face, arch chipping, caving and roof fall, which even damage preliminary bracing and permanent lining. After starting to excavate tunnel, the rock such as mudstone is likely to be weathered; due to the influence of underground water, partial rock mass is likely to soften and disintegrate in water, so as to decrease interlayer binding force, which is likely to trigger peeling, chipping and small scale of collapse. In structure destroy zone, the rock in severe wreathing usually form underground enrichment, which is likely to gather groundwater, generate water penetration during construction, and even trigger water gushing and mud bursting. It is especially severe in the part where groundwater is abundant; or large distribution of mudstone and sandstone in thin stratified structure.

Certain expressway tunnel in Sichuan excavated the interlayer fissure with catchment and water conductivity property, which makes groundwater in interlayer fissure gush out with causing water bursting in this tunnel. According to relevant data analysis, the surrounding rock mainly consists of broken siltstone with silty mudstone, cataclasite, and conglomerate; the joint fissure is developed; Ground water is bedrock fissure water gathering in bedrock fissure, fault zone and conglomerate fissure. Due to abundant rainfall, the fissure and solution crack water in water-bearing stratum is abundant; groundwater moves along bed and joint surface, so that the water containing systems not or partially connected are in hydraulic connection. Since the buried depth of tunnel in this segment is large and the ground water carries certain height of water head, the water containing system exposed by water gushing point carries higher hydrostatic pressure in earlier stage, which leads tunnel face to

occur sidewall deformation as well as invasion, and lifting of hole bottom; all these in turn trigger water and mud bursting with causing water gushing in tunnel.

4. Conclusion

(1) Red bed mainly consists of clay mineral and fragmentary substances, where the illite in clay mineral is a strong hydrophilic mineral, so the water character of rock in red bed region presents strong hydrophilic, easy to be softened in water, easy to disintegrate out of water and low strength; meanwhile, it softens and generates plastic deformation under the action of water, which changes the characteristics of rock. Influenced by structure and landform, it is likely to induce engineering problems.

(2) Due to the compact rock structure in red bed region, underdeveloped fissure, and small permeability coefficient, the rainfall infiltration and replenishment are impeded. The soft rock in red bed region is easily to be softened in water with high compressibility and low bearing capacity, which directly influences engineering property in red bed. Considering the weak anti-weathering ability of red beds, feldspar and mica are likely to the eroded and form intergranular pore, which, under the action of water, lowers pressure between pores and indirectly influences engineering property of red bed.

(3) It is suggested that, during the engineering, red bed can be considered as special rock so as to emphasize on its deformation, softness and poor stability. The more reasonable construction programs based on considering these problems in engineering activity help reduce emergencies, enhance stability during operation, and improve quality of newly constructed engineering.

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