

# 重庆丰都弹子台水库工程地质问题研究

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摘 要: 根据室内外大量调查测试资料, 对重庆市丰都县弹子台水库特殊的工程地质问题, 进行了阐述和深入系统分析, 所得结论为该水库的论证和设计提供了依据。

关键词: 水库研究; 岩体稳定; 库区边坡

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## 1 前言

拟建的弹子台水库, 位于重庆市丰都县包鸾镇东南 6.5 km, 长江二级支流——包鸾河上游。水库坝高 64 m, 库容  $1\ 000 \times 10^4\ m^3$ , 初步设计为混凝土面板堆石坝。水库的兴建主要为解决其下游  $0\ 333\ km^2$  农田灌溉和丰都县迁建新县城居民饮用水问题, 附带装机 1 200 kW。经可行性论证, 选定黑石坪作为初设坝址。勘探资料表明, 坝址和库区存在下列特殊工程地质问题: 一是坝址区右岸边坡中部岩层接触关系出现异常, 是否为滑坡所致; 二是河床钻孔岩芯破碎, 呈不连续状分布, 是否构成坝基潜在滑动面; 三是库区存在岩溶发育的灰岩, 是否存在库水渗漏问题。为此, 本文就上述问题进行阐述和分析, 为该水库的论证和设计提供依据。

## 2 坝区工程地质环境基本特征

工程区属低山丘陵区, 整体上呈 NNE 向展布的“两岭夹一槽”的地形特征。坝址区河谷呈不对称“V”字型, 河谷底宽 200 m 左右, 河谷高程约 635 m, 边坡高 100 余 m, 坡度约 40°。坝区地层岩性主要为侏罗系薄~中厚互层状长石石英砂岩、泥岩、砂质泥岩和粉砂岩, 该套地层为河相沉积物, 斜层理和薄透镜状软弱夹层发育, 岩层走向 NNW~SSE。坝区位于 NNE~SSW 向展布的弹子台不对称向斜轴部。受 NWW~SEE 向构造控制, 坝址区节理发育, 优势面主要有 4 组, 按其优度值排列, 顺序为  $N76^\circ W \wedge NE\ 83^\circ$ 、 $N2^\circ W \wedge NE\ 77^\circ$ 、 $N35^\circ W \wedge SE\ 78^\circ$  和  $N55^\circ W \wedge SW\ 81^\circ$ 。节理发育密度为 0.5~4.0 条/m。  $N76^\circ W \wedge NE\ 83^\circ$  组节理延伸大于 10 m, 其余组节理延伸多为 1.0~8.0 m。坝区现今地应力场以自重应力为主, 坝址区区域地质及坝区工程地质特征如图 1 和图 2 所示。

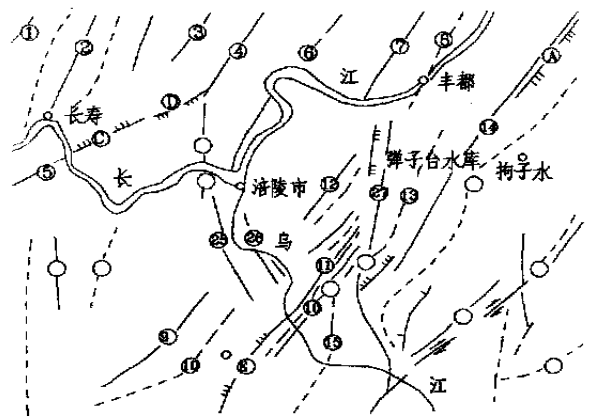


图 1 工程区及外围地区构造纲要图(1:133 万)  
1. 背斜轴及编号 2. 向斜轴及编号 3. 压性断裂 4. 张性断裂 5. 扭性断裂  
(注: ① 弹子台向斜 ② 方斗山背斜 ③ 大耳子背斜)

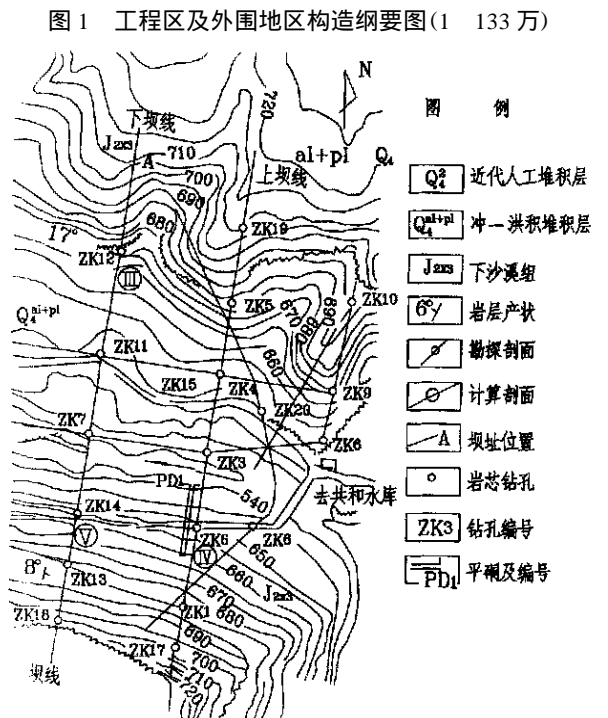


图 2 坝址区工程地质及勘探布置图(1:5600)

坝区岩体可分为长石砂岩、泥质砂岩、砂质泥岩、软弱夹层及破碎带、强卸荷及强风化带、弱风化

及弱卸荷带和第四系松散堆积物 7 种工程地质岩组。各岩组岩体物理力学参数如表 1 所列。

### 3 坝址区右岸边坡岩体变形现象及其成因机制

勘探资料显示,右岸边坡中出现薄层软弱夹层与顶、底板长石砂岩和泥质砂岩呈角度不整合接触(见图 3),接近边坡面这种现象更加明显,到边坡深部夹层变薄并过渡到岩层面。据分析,其成因有两种可能,一是构造,二是边坡蠕滑变形。调查情况表明,夹层顶、底岩层产状一致,层位连续,不存在连通性变形滑移带、后缘拉裂带和错动带。错动现象仅出现在弹子台向斜轴部较浅的部位,错动带夹层无泥化,也无特殊地下水活动现象。由此可见,上述现象是在河流下切、边坡岩体垂直方向卸荷过程中,引起的表生改造效应所致。其形成模式如图 3 所示。

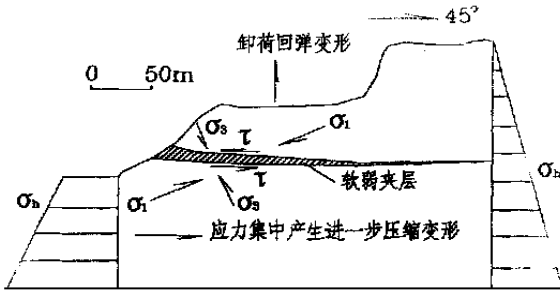


图 3 斜坡软弱夹层错动变形模式图

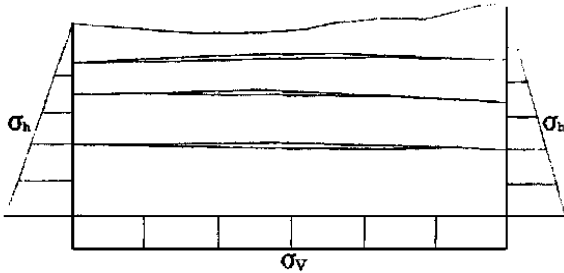


图 4 河谷表生变形模式示意图

由区域地质可知,坝区岩层层面起伏明显,软弱夹层分布不稳定,构造上又位于弹子台短轴向斜中部,岩层在水平地应力作用下,河流下切形成斜坡,软弱夹层以下岩层因河谷应力集中,斜坡切向应力增加,岩层进一步压缩变形;斜坡法向应力降低,剪切应力增加,岩层在斜坡法向产生回弹变形,导致斜坡软弱夹层错动变形,错动成“S”状岩块和裂隙。这种现象的特点就象现场显示的那样,愈到斜坡内部错动变形愈小,并逐渐过渡到不变形带。显然,此现象并非斜坡变形滑动所致。

### 4 坝区河床岩层破碎带及其成因机制

钻孔资料显示,河谷和 I 级阶地钻孔岩芯破碎,个别钻孔岩芯已风化成沙糖状。破碎带在高程上呈不连续带状分布,破碎带上、下岩石多为泥质砂岩。根据破碎带高程分析,破碎带的形成机制仍与河谷

表生改造有关。岩层在水平方向受构造力与岩层自重产生的水平作用力迭加,河流下切引起的应力集中,使水平作用力进一步增加,而垂直应力降低,岩层产生了如图 4 所示的“压杆”式弯曲隆起变形。例如,河谷宽 100 m,岩层平均厚度 0.8 m,变模平均 1.620 MPa,则水平作用力  $P_c$  为:

$$P_c = \frac{\pi^2 E I}{l^2} = \frac{3.14^2 \times 1.620 \times 10^3 \times 0.8^3 / 12}{100^2} = 68.22 \text{ (kN)} \quad (1)$$

时,河谷岩层将产生隆起变形。即,水平地应力  $\sigma_h$  为 85.28 kPa 时,岩层就会产生“压杆”式弯曲隆起变形。若考虑岩层自重应力作用,  $\sigma_h$  应比 85.28 kPa 大,岩层才会产生上述变形失稳。若不考虑岩层自重作用,考虑岩层被节理切割成块体而不是完整连续体,则  $\sigma_h$  应比 85.28 kPa 小,岩层就会产生上述变形。若同时考虑岩层自重和节理切割作用,  $\sigma_h$  达到 500 kPa,岩层才会产生垂直隆起变形,导致层间虚脱架空。实际上,不考虑构造应力,仅 100 余 m 厚的两岸岩层的自重产生的水平应力  $\sigma_h$  可达

$$\sigma_h = \gamma \times h \times \frac{\mu}{1 - \mu} = 25 \times 100 \times \frac{0.205}{1 - 0.205} = 644.65 \text{ (kPa)} \quad (2)$$

因此,河床岩层具备上述卸荷隆起变形,使层间虚脱架空式的变形条件。岩层层面虚脱后,下覆岩层垂向应力降低很多,加上节理切割、风化和地下水渗流作用,使泥质砂岩破碎。局部碎裂岩体中的粘粒被地下水带走后,就成了砂糖状。坝区剖面有限元分析结果也表明,河床水平向应力出现集中现象(达 5 MPa),垂直向出现 0.05~1.0 MPa 的拉应力。这也说明了河床岩层具备了上述变形的力学条件。

### 5 库区渗漏问题分析

库区调查发现,在板桥~公安桥(见图 5)一带河谷两岸分布块状、碎裂状、层面杂乱模糊不清、溶洞溶孔等喀斯特现象发育的灰岩,其下部为  $J_{2x5}$  及  $J_{2x}$  的砂岩及砂质泥岩。经室内外鉴定,灰岩属二迭系茅口组生物灰岩、含硅质结核的长兴组灰岩,富含有机质的栖霞组生物灰岩及风化面呈灰黑色的白云质灰岩。地形上,该段灰岩构成的河谷两侧形成高达 30 m 的陡崖和峡谷。公安桥上游两个支流均为宽谷,基座阶地发育。支流高出河床约 15 m 的北侧,沉积了一套二元结构明显的卵石层,见图 6。

卵石层顶面沉积了一层 1~30 cm 厚、连续的、胶结较好的泥质、钙质及铁质混合物。卵石层下部是以灰岩碎块体为主的崩坡积物。板桥~公安桥一带东侧斜坡广泛分布有灰岩及白云质灰岩碎块石。

据上述现象分析,此段灰岩来源于东侧山顶二

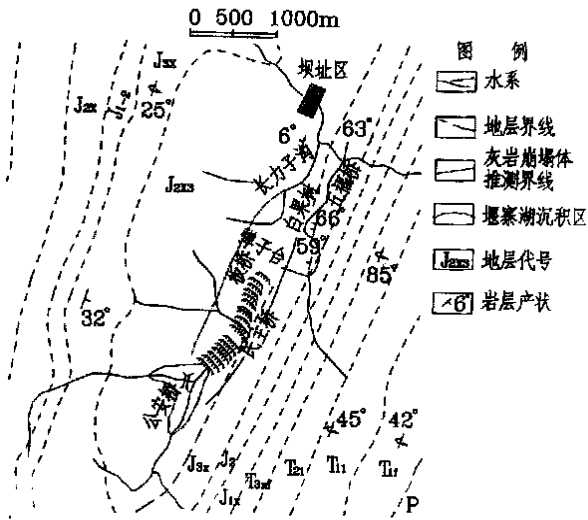


图5 库尾岸坡崩塌体分布及塞湖沉积区示意图

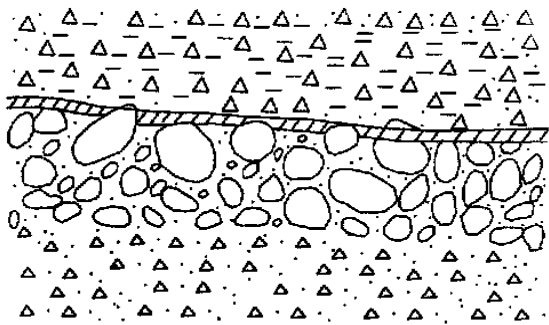


图6 堰塞湖沉积的卵石层结构特征示意图  
1-沙卵石层; 2-泥质, 铁质胶结物盖层; 3-崩积物; 4-坡残积物

迭系的古崩塌体。其形成条件如图7所示。处于弹子台向斜的软弱砂质泥岩, 风化剥蚀形成包鸾河。河谷东南侧坡顶为裂隙发育、坚硬的二迭系灰岩; 斜坡中部为较易风化的  $T_1 \sim T_3$  泥灰岩、泥质灰岩、泥质砂岩。由于卸荷和差异风化, 形成了上硬下软的反倾陡坡。随着陡坡下部相对软层的变形, 上部灰岩中的裂隙, 因坡体表层切应力由原来的压应力变为拉应力、扩展贯通, 形成拉裂隙, 并随着下部相对软弱岩层进一步风化、剥蚀和变形, 拉裂隙向陡岩下部贯通产生崩滑, 崩滑体堵塞包鸾河, 在公安桥上游一带形成堰塞湖, 并在原坡积物上沉积了近 30m 厚、具二元结构的沙卵石层。后来堆石坝冲刷溃决, 形成了目前的小峡谷, 堰塞湖中的沉积物被破坏, 而岸上的沉积物被保留下来, 见图7。

(上接第7页)

向”, 符合坚持“政企分开, 省为实体, 联合电网, 统一调度”的政策。也是贫困山区农村脱贫致富的重要途径, 建议国家给予重点扶持。

## 6 结论

据弹子台水库上述特殊工程地质问题的分析, 可以总结出以下几点结论:

(1) 坝址区右岸软弱夹层出现错动变形现象不是滑坡所致, 而是地层沉积环境不稳定, 沉积的软弱夹层厚度不等, 加之河流下切, 河谷产生的改造效应, 目前还没有形成贯通性软弱面, 发展成滑坡的条件。

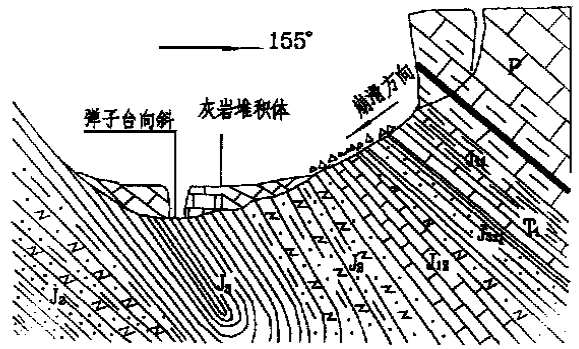


图7 灰岩崩滑体形成及堆积特征示意图

(2) 坝址区河床岩层破碎松动带是在构造基础上, 河谷次生改造的结果。破碎松动带并未贯通, 对堆石坝来说, 不构成稳定问题, 仅对水库渗漏和坝基变形有影响。只要帷幕止水设计、坝基设计和施工予以重视, 对水坝不会构成威胁。

(3) 库尾河床灰岩属其东南侧(左岸)山顶二迭系灰岩崩滑堆积物, 水库正常蓄水位以下全为侏罗系泥质砂岩、砂质泥岩和砂岩且不具备岩溶通道, 故不存在水库渗漏。

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## ABSTRACT

### The Neural Network Model for Reservoir Operation

FU Shipeng ZHAO Wen-qian MA Guang-wen

(State Key Hydraulic Laboratory of High Velocity Flow of Sichuan University, Chengdu, Sichuan 610065)

**Abstract** Because there are much nonlinear relationship in reservoir operation, good results are hard to gained by using traditional linear relationship. Therefore, a neural network model for long tem reservoir operation is established by BP algorithm. It is more practical and superior.

**Key words** reservoir operation; neural network; BP algorithm

### Application of Artificial Neural Network Model with Nonlinear Time Series in Hydrologic Forecast

WANG Wen-sheng DENG Jing LIU Guo-dong

(Sichuan University, Chengdu, Sichuan, 610065, China)

**Abstract** At first, the artificial neural network(ANN) models with nonlinear time series are established, then time series for single variable and multiple variables are studied with the models. The performance of the ANNs is compared with that of the auto-regressive models. The results have showed that the ANNs are effective in hydrologic forecast.

**Key words** the artificial neural network models with nonlinear time series; auto-regressive model; single variable; multiple variables; daily discharge forecasting

### Application of Percolation Theory in the Water and Soil Conservation for Slope

WANG Xie-kang AO Ru-zhuang FANG Duo

(State Key Hydraulic Laboratory of High Velocity Flow of Sichuan University, Chengdu, Sichuan, 610065, China)

**Abstract** The slope erosion is the original zone of water and soil loss and water and soil on slope must be treated quickly. because rainfall infiltration on slope, afflux and sediment transport is a percolating process, water and soil conservation for cultivated and non-cultivated land on slope is carried out by the percolation theory. Comparing percolation thresholds among the different tow-dimensional percolation models, theoretically, water and soil loss is effectively controlled on slope with honeycomb shape and by hydraulic and biological engineering, which is a new method for water and soil conservation.

**Key words** slope erosion; water and soil loss; percolation theory; biological engineering

### Study on Engineering Geological Problems at Tanzitai Reservoir in Fengdu County of Chongqing

DENG Rong-gui FU Xiaom in

(Civil Engineering Department of Chengdu Technical Institute, Chengdu, Sichuan, 610059, China)

**Abstract** Based on numerous data obtained from field investigations, detail description and in-depth, systematical analysis on engineering geological problems at Tanzitai reservoir in Fengdu County of Chongqing are provided and the results are used as design basis for Tanzitai reservoir.

**Key words** reservoir analysis; stability of rock mass; reservoir slope

### Nonlinear Properties of Furrow Profiles of Debris Flow in Bailong River Basin

WANG Xie-kang AO Ru-zhuang FANG Duo

(State Key Hydraulic Laboratory of High Velocity Flow of Sichuan University, Chengdu, Sichuan, 610065, China)

**Abstract** Debris flow is a nonlinear dynamic process, so the furrows of debris flow have nonlinear properties. Based on analysis of dynamic factors of debris flow growth, accumulative distribution of furrows of debris flow in function with its dynamic factors is studied by fractal theory. The results are satisfactory and benefit for study on debris flow in the Bailong River Basin and Jialingjiang River Basin.

**Key words** debris flow; nonlinear; fractal theory

### Experimental study on the Hydraulics Characteristics of Intermittent Disposed Buoyant Flows

YU Guo-liang<sup>1</sup> AO Ru-zhuang<sup>1</sup> LIAO Neiping<sup>2</sup>

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2. Southwest Electricity Survey and Design Institute Chengdu, Sichuan, 610061, China)

**Abstract** There are two ways discharge of sewage water into ocean. In addition to the conventional way, the other is intermittent discharge, which is widely used, in recent decades. The hydraulic characteristics of intermittent disposed buoyant flows were preliminary experimentally studied and the differences of the hydraulic characteristics between intermittent discharge and steady discharge were compared in this paper.

**Key words** buoyant flows; hydraulic characteristics; intermittent discharge; steady discharge

### Several Problems Being Worth Notice in Management of Project with Foreign Funds

JU Qifeng

(Sichuan Ertan International Engineering Consulting Co. Ltd.,

CHDI of SPC, Chengdu, Sichuan, 610072, China)

**Abstract** In the management of projects with foreign funds, some aspects are worth discussing and improving. Then, the construction market of China will be perfect day by day and transform into international practice smoothly. Experiences and lessons gained from practice in management of project with foreign funds in Ertan Project are presented for reference to similar projects.

**Key words** project with foreign funds; problem; relationship; exchange rate; escalation; subcontract; division into lots; supply; claim indemnity