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四川九寨黄龙机场高填方地基变形与稳定性系统研究

刘　宏[1,2]

(1. 喀斯特环境与地质灾害防治教育部重点实验室，(贵州大学)贵州 贵阳 550003；
2. 成都理工大学工程地质研究所，四川 成都 610059)

关键词：九寨黄龙机场；高填方地基；变形；稳定；系统研究
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随着我国西部大开发战略实施，多山的西南地区机场建设进入迅猛发展阶段。这些机场的特点是高填方、高地震烈度、场区地质条件复杂、常分布有软弱土层，且机场建设周期短。因而妥善解决机场高填方地基的稳定与变形(沉降与差异沉降)是该地区机场建设的核心问题和首要问题。但国内外对机场高填方地基变形与稳定性系统研究仍不多见，甚至连“高填方”的标准也无统一定论。九寨黄龙机场场区基本地震烈度 8.1 度，海拔 3 442 m，最大填方高度 104 m，土石挖填方量超过 5 800 万 m^3，底部软弱土层厚达 10 余 m。本文基于前人的初勘、详勘基础地质资料和环境工程地质评价，开展了高填方地基处理检测试验、砂砾石填料压缩蠕变试验、高填方地基变形与稳定性离心模型试验和数值模拟研究、以及长达 2 年的高填方地基变形原位监测，形成了九寨黄龙机场高填方地基变形与稳定性系统研究体系，并获得了以下几点创造性成果。

(1)以大量的试验和观测资料，丰富并完善了前人关于九寨黄龙机场高填方地基变形与稳定性的系统研究设想，认为高填方地基工程研究、设计与施工必须紧密结合：第一，开展高填方地基基础地质条件研究和环境工程地质评价；第二，结合工程情况进行高填方地基变形与稳定性试验研究并提出软弱地基处理方法；第三，进行软弱地基处理试验和填料碾压夯实试验；第四，结合工程实践进行高填方地基变形与稳定性原位监测，并结合监测研究成果对前期试验研究进行反馈分析；第五，综合各阶段研究成果，对高填方地基将来的变形与稳定进行预测，并以此为依据进行下一阶段工程设计；

(2)软弱土是原地基中相对软弱土层，其力学性质较一般土层为差，却高于软土，不是真正意义上的软土。但它对高填方地基稳定性和地基沉降与不均匀沉降起着决定性作用，对其应根据实际情况进行强夯、碎石桩、换填和碾压处理；

(3)初始压实度控制着砂砾石填料的压缩变形特性，初始压实度为 97.4%的砂砾石填料压缩变形过程具对数函数特征，而初始压实度大于 99%的砂砾石填料压缩变形过程则以线性函数特征为主；

(4)高填方地基沉降包括底部原地基沉降和填筑体压缩沉降两部分。原地基(尤其是强夯地基)沉降是软弱土体较为缓慢的排水固结过程，填筑体沉降则是非饱和土体的快速自重压密过程，两者对荷载响应特性有较大区别。前者的沉降曲线较为舒缓，沉降随荷载增加而逐渐发展，在停止加载后一段时期内，沉降速率才逐渐降低。后者加载期间沉降曲线陡而急，快速加载产生快速沉降，加载停止后，沉降速率迅速减小，导致加载期间沉降曲线与停止加载后沉降曲线之间存在明显拐点，并随工程间歇性施工加载沉降随加载呈阶坎状发展；

(5)高填方地基工后沉降包括填筑过程中产生的部分瞬时沉降、加载结束后的主固结和次固结三部分，瞬时沉降速率最高可达 0.20 m/月，发展时间约为 15～40 d，主固结速率为 0.003～0.03 m/月，发展时间为 8～14 月，次固结速率小于 0.003 m/月，发展时间为 3～5 年；

(6)元山子沟高填方地基在发生 0.256 m 侧向位移，月平均位移速率高达 6.02 cm/月条件下仍处于稳定状态，且深部并未出现沿某个层面滑移，有力

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作者简介：刘宏(1976—)，男，博士，2003 年 7 月毕业于成都理工大学工程地质研究所，现为贵州工业大学省喀斯特环境与地质灾害防治重点实验室项目博士后，主要研究方向为岩体稳定、地质灾害与防治等。E—mail：liuhsohu1234@sohu.com

指导了机场土石方工程顺利施工。土石方工程结束后，综合各阶段研究成果，以人工神经网络模型、回归参数模型和工程地质类比等方法对高填方地基工后沉降进行了预测，认为道槽区最大工后沉降量较小，元山子沟为 0.57～0.65 m，设计沟为 0.27～0.30 m，山巴沟为 0.18～0.26 m。为下一阶段场道工程设计与施工提供了坚实的理论依据，实现了九寨黄龙机场高填方地基变形与稳定性系统研究方法的生产实践意义。

A SYSTEMATIC RESEARCH ON THE DEFORMATION AND STABILITY OF HIGH EMBANKMENT OF JIUZHAI－HUANGLONG AIRPORT，SICHUAN CHINA

LIU Hong

(1. Key Laborang of karst Enviroment and Geohaard Prevention(Guizhou univoersioy), Minising of Education, Guiyan 550003, 2. Engineering geology institute, Cheng du University of science and Techndog. Sichuan Cheng Du 610059 China)

Abstract

With the great development of West China, the airport construction in the mountainous southwest of China is coming into a prosperous period. High embankment, intensive earthquake, complex geological conditions accompanied with soft soil, and short construction period are the main characteristics for these airports. Therefore, properly dealing with the stability and deformation (settlement and differential settlement) of the high embankment during the construction is the first and nuclear task in these regions. But little research has been carried out about the stability and deformation of the high embankment either domestic or abroad. So much as the standard of high embankment height is still violently disputed. The site of Jiuzhai－huanglong airport is located in the 8. I degree of seismic intensity zone, and its elevation is 3442 m. The maximum height of the embankment is 104 m. The total quantity of the excavated and filled earth－rock material is above 58,000,000 m^3. The thickness of the weak soil under the embankment is above 10 m. In this dissertation, based on the predecessors' research for the basic geological conditions in the preliminary and detailed investigation, and the evaluations of the environmental engineering geology, ground treatment detection tests, coarse grain filling material compressional creep tests, centrifugal model tests and 2－year in－situ monitoring and numerical simulations for the stability and deformation of the high embankment of Jiuzhai－huanglong airport are carried out. Some creative conclusions are put out as follow.

①The research system of the deformation and stability of the high embankment of Jiuzhai－huanglong airport assumed by predecessors is improved and enriched by large numbers of tests and monitoring data. It's recommended strongly that research, design and construction be integrated tightly. That's first, study the basic geologic conditions of the high embankment and carry out its environmental geologic engineering assessment. Second, associating with the engineering situation, carry out the deformation and stability of the high embankment tests and work out the reinforcement of the weak ground. Third, actualize the reinforcement tests of the weak ground and the rolling compaction tests of the filling material. Forth, implement the in situ monitoring during the whole construction period and feed the monitoring results back to the prophase tests study in time. Fifth, Based on the comprehensive analysis of all research results, predict the coming deformation and stability of the high embankment, then to the next stage's design.

②The weak soil is a weak stratum comparing with others, not the regular soft soil. Its mechanical property is below regular soil, but above soft soil. The weak soil is crucial for the high embankment stability and settlement, especially the differential settlement, thus must be reinforced, according to the situation, by dynamic consolidation, gravel pile, cushion or rolling.

③The initial degree of compaction of grit filling controls its compressional characteristics. If the initial degree of compaction is 97.4%, the compaction process is logarithmic. If it is above 99%, the process is linear.

④The settlement of the high embankment is composed of the settlement of the ground and the compression of the embankment itself. The ground settlement (especially the settlement of the ground which reinforced by the dynamic consolidation) is a slowly draining consolidation of weak soil, and the embankment compression is a fast process of unsaturated soil compaction

under its self—weight. The difference of their response to loading is remarkable. The former settlement curves are gentle and smooth, that's the settlement increases gradually with loading, and its velocity diminishes bit by bit after loading. The latter settlement curves during loading are steep, that's fast loading produces fast compression, and its velocity diminishes speedily after loading. Therefore, a remarkable knee point comes into being between them. With intermittently filling process, the settlement curves develop ladder-likely.

⑤The settlement that occurs after the embankment attained its scheduled level is composed of immediate settlement occurring during the filling process and primary consolidation and secondary consolidation occurring after the loading process. The maximum immediate settlement velocity is 0.20m/month, its life time is about 15～40 days. The primary consolidation velocity is 0.003～0.03m/month, its life time is about 8～14 months. The secondary consolidation velocity is below 0.003m/month, its life time is about 3～5 years.

⑥Though the lateral displacement of the high embankment located in Yuanshanzigou is above 0.256 m with a recorded velocity of 6.02cm/month, it is still stable and deep slip surface is nonexistent. Based on the comprehensive analysis of all research results, the settlement that occurs after the embankment attained its scheduled level is predicted by the artificial neural net work and the regressive parameters models and the engineering geologic analogism. The results show that the maximum settlements of Yuanshanzigou is 0.57～0.65 m, and Shejigou is 0.27～0.30 m, Shanbagou is 0.18～0.26 m. All theoretically guide the filling process and provide a solid basis for the next stage's design and construction and actualize the creative and practical purpose of the research system of the deformation and stability of the high embankment of Jiuzhai-huanglong airport.

Key words: Jiuzhai-huanglong airport; high embankment; deformation; stability; systematic research