

Research on the Mechanical Analysis of Weathered Rock Filling Subgrade on Highway

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ABSTRACT: *With the rapid development of national economic construction, traffic network is extending continuously, and the scope of the highway construction is gradually shifting from plain to the mountains. However, weathered rock occupies heavily along highway in mountainous area, and high quality subgrade filling is extremely short, thus a large amount of subgrade filling needed for subgrade high-fill and deep-cut of highway cannot be met. Therefore, based on the grading standard of the degree of rock weathering, and combined with the analysis and research of weathered rock engineering characteristics, the weathered rock filling subgrade that met the engineering requirements was selected in this paper. At last, the bearing capacity and stability of subgrade material were judged according to the analysis of the mechanical property. It provides scientific basis for the local materials of highway construction, and has important practical significance for solving subgrade filling shortage of highway in mountain areas and accelerating highway construction in mountain areas and promoting economic development.*

Subject Categories and Descriptors

G.1.3[Numerical Linear Algebra]: Numerical Analysis;

G.3[Probability and Statistics]Loss Ratio

General Terms

Computational Method, Numerical Analysis

Keywords: Weathering Rock, Subgrade Filling, Engineering Characteristics, Mechanical Analysis

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1. Introduction

With the rapid development of national highway construction, the focus of the highway construction are moving from the eastern developed cities to the western mountains, and more and more terrain along the highway has been moving from micro plain hill area to the heavy-hilly area. In this transformation process, short of high quality road materials is the biggest factor that influence the mountainous area highway construction. Stone filled subgrade is mostly confined to high quality stone. But for mountainous highway, sources of high quality stone material along the highway are limited. Local material is the best choice of the highway subgrade filling [1]. However, under the action of natural and human factors, most of rocks have been evolved into weathering rocks of varying degrees. Compared with good stone padding, new and higher requirements of subgrade slope processing, structural style, and drainage and bearing capacity have been raised in subgrade filled with weathering stones. More than that, the broken feature of weathering stone is significantly different from that of good stone material. However, the quality of stone cannot be controlled for lacking of the technical index of this kind of stone. Thus it can be seen that the research of the construction of weathering stone filling subgrade and its detecting technique has become the problem of getting through provincial boundary line channel that is badly needed to be solved. There

fore, experts in China have launched lots of researches on it. In paper Deformation Characteristics of Road Filling of Soft Metamorphic Rock before and after Soaking in Qinling-Bashan Mountainous Region [2], Yang Lingyun adopted the method of the combination of laboratory test and field test. In the perspective of the engineering characteristic of packing, compaction process, engineering application, etc, it has provided important pushing action for improving the traffic environment in Qinling Mountains and the surrounding areas. In paper Study on Highly Weathered Phyllite Filling Subgrade Technical Highway [3], and under the basis of intense weathered phyllite protolith basic physical mechanical test and packing engineering characteristic test, Mao Xuesong, et al conducted improvement on padding whose bearing ratio does not meet the highway roadbed filling mechanical properties. It has solved the problems like the lack of subgrade padding and the soil of farmland. In paper Observation and Research of Weathered Rock Subgrade Settlement [4], in order to reveal the engineering properties of weathered rock filling subgrade, Han Wei combined the indoor compaction test and settlement observation experiment in construction side. He conducted in-depth analysis on the rule of the weathered rock subgrade settlement changing with the time. At the same time, he summarized the slope protection of weathered rock filling subgrade. The

research of this paper was aimed at providing guidance and evaluation on highway weathered rock subgrade filling in mountainous area, which has certain economic and social benefits.

2. Research Status of Weathered Rock Subgrade Filling

From In the perspective of material, weathered stone is the product of rock after different degrees of weathering. Therefore, research achievements of rockfill subgrade can be served as the reference of weathered rock filling subgrade. The domestic study of rockfill subgrade has been launched from the beginning of the last century, which was of guiding significance for construction of the weathered rock subgrade [5]. Since entering into the new century, and as the highway construction is carried forward in mountainous area, applied researches of weathered stone in highway construction are also gradually unfolded. They not only divided the qualitative standard of weathered rock, but also regulated that the slope form of subgrade should be designed according to soil subgrade slope form when easily weathered rock and soft rock are used as roadbed filler. The specific classification standards of weathering degree are shown in TABLE 1:

Weathering degree	Features
Weak weathering	The rock quality is fresh with slight signs of weathering in its surface
Medium weathering	<ol style="list-style-type: none"> 1. Clear structure and structural layer 2. Rock mass joints, fractured was divided into blocks (20cm—50cm), a small amount of weathering was filled in fissure, hammer sound is crisp, and easy to break. 3. It is difficult to excavate with pickax, only drill in core
Intense weathering	<ol style="list-style-type: none"> 1. The structure and structure layer were not very clear, and mineral composition had been significant changed 2. Rock mass joint was divided into gravel shape(2cmN20cm), and gravel can be broke by hand. 3. It can be excavated with pickax, and it is not easy to enter into with hand drill.

Table 1: Division of rock weathering degree

Regulations of the embankment slope ratio of rock fill highway are shown in TABLE 2:

Types of rockfill	Total height	Upper level height	Lower level height	Upper level height	Lower level height
Hard rock	20	8	12	1:1.1	1:1.3
Medium hard rock	20	8	12	1:1.3	1:1.5
Soft rock	20	8	12	1:1.5	1:1.75

Table 2. The embankment slope ratio of rock fill highway

3. Researches of the Engineering Characteristics of Weathered Rock Subgrade Filling

The weathered rock subgrade filling refers to the mixture of different size particles. Compared with the ordinary rock

fill and fill subgrade filling, it had many disadvantages, such as low intensity, poor ability of weathering resistance, easy expansion under the influence of water, dramatic decline of bearing capacity, etc. Compared with other packing, its engineering property is of obvious deficiency.

In the process of filling compaction, not only the control of grain composition could not be adopted to reach its maximum density just like hard stone packing, but also could not break the ballast piling into soil and controlled it through the optimum water content[6]. Therefore, it is of great significance to comprehensively study the engineering properties of weathered rock filling, find a reasonable and effective method of the weathered rock subgrade filling, and scientifically uses certain degree of weathering of rock filler to highway subgrade filling in mountainous area.

3.1 Compaction and Structural Characteristics

3.1.1 Compaction Characteristics of Rockfill Subgrade

After paving, the internal stress state of relatively loose gravel packing will change under the action of external force compaction work. These particles overcome the friction between each other, move to each other and fill each other. New particles composition arrangement appears which caused the decrease of porosity and increase of density. As the applied external force is becoming larger, the energy of filling will be increasingly greater and the stone particles are increasingly dense. When the external force reaches to a certain degree, a new and more stable balancing of stress [7] will be reached among particles. Though the compaction function is increased, particles are not easy to move. At this time, the tiny cracks inside the stone extend and connect under stress, thus the stone is broken. It breaks the stress balance inside the stone, and these particles move to each other and filling again until stable structural state is formed.

3.1.2 Structural Characteristics

Due to the particularity of its material composition, there is no cohesive force between particles of stone filled subgrade. The formation of strength is mainly relying on embedded crowded structure among particles. There are many good engineering characteristics of formed subgrade, such as stable structure, strong carrying capacity, large compaction density, strong water permeability, small sedimentation, etc. Skeleton structure figure that is formed during rolling is shown in figure 2.1:

3.2 Broken Features

Under the perfect state that the particle strength of rockfill subgrade filling is large enough and its shape is round enough, the padding under construction will not be crushed. However, uniaxial compressive strength of subgrade filling stone can be up to thousands of MPa, and particles are of different size and shape. There exists no perfect state. In addition, macadam filling is generally mined by artificial blasting. Many potential deficiencies exist inside the particles. Combined with the irregular shape of the particles and the relatively larger friction among particles, the padding is easy to produce grain breakage under road roller pressure when the strength of the filler particles is lower and more interspace are formed because of bad particle size.

If the forces act on the corner of stone filling is greater than the strength of the stone itself, then the phenomenon of stone corner breakage is prone to happen. The forces of stone particle corner on other stones will be increased with the increase of applied external force, and then more grain breakage will happen. It causes the rearrangement of stone, change of particle size composition and formation of compaction structure again. If the continuous external force infliction cannot break this balance, then the structure will be in a stable state [8]. On the contrary, if the external force is very large, and the new produced stone particles corners are crushed again, then the above process will be repeated. In addition, for there exist tiny crack inside the stone itself, cracks will expand, break through and appear broken phenomenon if compaction function is continuously increased. The balancing of stress inside the stone particles will be broken again. Stone particles will move to each other again and filling and structure will be gradually in a stable and close-grain balance state. In a word, the broken of rockfill subgrade filling mainly includes two types: corner breakage and internal microcrack cut-through.

3.3 Long-term Stability

Due to weathering, the strength of subgrade filling after weathering is decreased. And its compaction breakage features are different from ordinary rockfill subgrade. The broken situation during construction is worse than that of ordinary rockfill subgrade. However, in the process of long term usage after the completion, the performance of weathered rock subgrade filling particles is also not static. And these properties are related to factors like weathering degree of packing, products formed by weathering, subgrade drainage, etc. The specific influences are as the following several aspects: (1) the weathering degree of subgrade filling: the content of hydrophilic clay minerals in weathered debris, like montmorillonite, illite, kaolinite, etc are different as the different of weathering degree. These hydrophilic clay minerals are with the characteristics of fine particle composition, high bibulous rate, large specific surface area, etc. Under the condition of fully immersion, the erosion of water in packing porosity will cause softening and broken of subgrade filling, and whole bearing of subgrade. (2) The influence of water and load: for there contains considerable hydrophilic clay minerals in weathered rock filling subgrade filler, not only the swelling and disintegration of filling particles be accelerated by water, but also more secondary clay minerals will be produced. It brings about serious influence on the long term stability of subgrade. (3) influence of filling weathered secondary clay minerals: for the influence of the change of water and temperature, further weathering alteration of weathered rock filling will be happened. Thus two types of secondary mineral will be formed. One is of solubility, the other insolubility. After the soluble secondary mineral solute in water, soluble halide, sulfate and carbonate are formed because of evaporation. These salts are generally crystallization and sedimentation and filled in the hole of rock. Then unstable cement is formed. However, those do not precipitate out

will exist in the rock pore solution in ion status. The interaction of the solution with clay particles influences the long term stability of weathered filling subgrade.

4. Analyses of the Mechanical Properties of Weathered Rock Subgrade

4.1 Power Transmission Characteristics of Weathered Rock Tested by Earth Pressure Cell

Subgrade should have enough bearing capacity and stability. Modulus of resilience is the key of subgrade structure bearing capacity index. At the same time of having enough carrying capacity, subgrade should also have good power transmission effect. Only in this way can subgrade top not be destroyed because of bearing too much pressure. Earth pressure cell is a very common tool used for testing the power transmission effect of weathered rock filling subgrade under roller vibration load. Through the measurement of soil pressure cell, it can be found that the less the weathered rock filling in pressure cell was, the poor stability the test would be. With the increase of filling height, the test results were more stable. Thus it can be judged that weathered rock subgrade filler is of good power transmission effect. The scene embedding and testing are shown respectively in figure 3.1 (a) and (b).

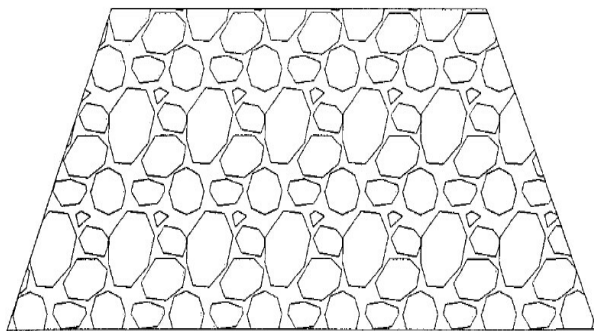


Figure 2.1. Skeleton structure formed by rockfill subgrade particles



Figure 3.1 (a) Pressure cell embedding



Figure. 3.1 (b) Site test

4.2 Influence of environmental factor on the mechanical property of weathered rock

Under the combined action of water, temperature and other natural factors, the weathered rock subgrade filling of subgrade filling would appear adverse phenomenon of engineering, like the decline of carrying capacity, swelling, etc, of which, under water action, the rebound modulus of structure was shown in table 3:

Table 3 indicated that within certain ranges, water content had little influence on rebound modulus. However, when the water content of subgrade structure was more than 14%, the rebound modulus was obviously decreased. Combined with the current highway roadbed specification, high speed weathered rock packing belongs to Micro dilatibility packing, and is sensitive to water. Therefore, in order to guarantee the stability of subgrade, the water content of weathered rock subgrade should be controlled within 10%.

5. Discussion

In recent years, with the start of upper level highway engineering in a large number of provincial boundaries, the constriction of highway in mountain areas have already become the bottleneck of restraining the development of national economy. The problems of weathering stone filling subgrade are increasingly prominent. Compared with the traditional filling subgrade stone, weathering stone has many adverse characteristics, like broken features, high requirement on subgrade, obvious environmental influence on late performance, etc. It increases the difficulty of highway construction [9-10]. Therefore, this paper aims to successfully apply weathered rock to mountainous area highway roadbed filling, ensure the usability of this material filling subgrade, reduce the problem of padding shortage under construction of highway subgrade in mountainous area and save a lot of cost of engineering. This paper analyzed the differences of engineering characteristics between weathered rock filling subgrade and ordinary rockfill subgrade based on the conclusion of research status of domestic weathered rock. This paper also summarized the objective factors that are needed to avoid when weathered rock is used as subgrade material. Through the analysis of the mechanical property of weathered rock, this paper solved the problem of how to reasonably and effectively use weathered rock subgrade filling.

subgrade moisture content (%)	6	10	14	18	22
rebound modulus (MPa)	76.4	74.3	71.6	66.4	58.3
loss ratio (%)	0	2.7	6.28	13.09	23.69

Table 3. Changing of rebound modulus with water content

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