Review Article

Review of research status of subgrade disease classification methods

ABSTRACT

Subgrade disease classification is one of the important means for highway management and maintenance departments to prevent and reduce disaster, and it is also the basis for using engineering analogy methods to prevent subgrade disease. For this reason, firstly, subgrade diseases are divided into slope diseases and subgrade subsidence and collapse diseases according to the definition. The formation and breeding conditions of the two types of subgrade diseases are analyzed from the aspects of topography, geological structure, formation lithology, meteorology and hydrology, human activities, and other factors. Then, the research status of classification methods of slope diseases and subgrade subsidence and collapse diseases is reviewed, and the existing classification methods of slope diseases are divided into single-factor index classification methodsand multi-factor index classification methods. Finally, the above classification methods are reviewed, which will provide guidance for the prevention and control of subgrade diseases.

Keywords:Subgrade disease; Slope disease; Classification method; Research status.

1. INTRODUCTION

1.1 Classification and definition of subgrade disease

In order to better prevent and reduce disasters, many scholars have used different methods to conduct in-depth research on the mechanism of subgradedisease from different angles. The purpose of theclassification of subgradedisease is to analyze and summarize the apparent characteristics ~~of subgrade disease~~ and the internal and external factors that induce its instability, ~~so as~~ to briefly reflect the internal law of similar subgrade disease instability. Scientific and reasonable classification of subgrade diseases can not only deepen the understanding of subgrade diseases but also quickly identify the attributes of subgrade diseases according to classification characteristics, ~~so as~~ to achieve the purpose of emergency prevention and control [1]. Therefore, subgrade disease classification research is a fundamental work of great significance. Subgrade disease includes slope disease and subsidence and collapse of thesubgrade itself. Subgrade refers to the belt structure built as the pavement foundation according to the route location and certain technical requirements (highway is composed ofasurface layer, base layer, and stratum, the concept of subgrade in this paper includes base layer and foundation), which is divided into embankment and cutting. Slope refers to the inclined plane connected to the ground on both sides of the subgrade cross-section. Corresponding to the subgrade, it is divided into embankment slope and cut slope, and is an important factor affecting the stability of the subgrade [2]. Slope diseases mainly include landslides, collapse,~~and~~ water damage, etc. There are two kinds of landslide concepts: one is broad, that is, all phenomena of slope rock and soil body moving down the

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slope are collectively ~~referred to~~known as landslides, ~~including~~encompassing events such as landslides, collapse, debris flow, etc. The other is narrow, that is, only the slope rock and soil body along a certain surface (belt) overall downward slide called landslide, this paper adopts the latter, both narrow definitions. Subsidence refers to the uneven vertical deformation caused by insufficient subgrade compaction or poor soil quality of structure foundation under the action of water, load and other factors. Collapse, also known as "sting-trap", is a dynamic geological phenomenon in which surface rock and soil fall downward under the action of natural or human factors and form a collapse pit (hole) on the ground. It is caused by uncompacted embankment soil, many pores, hidden loopholes, weak foundation or large load and other reasons [3].

1.2 Analysis of the formation and breeding conditions of subgrade disease

Subgrade disease is formed and bred under the joint action of internal and external factors. The internal causes include landform, geological structure, formation lithology, and other factors, which are the basic factors of the formation of subgrade disease. The external causes include meteorological and hydrological factors, and the mechanical response of subgrade and slope is the inducing factor of subgrade disease. Because the causes of slope disease and subgrade subsidence and collapse disease are not ~~exactly~~ the same, this paper will elaborate on the formation and breeding conditions of the two.

(1) Topography: slope diseases are bred and formed on the slope topography, and are the basic elements of slope diseases. The slope topography in nature is formed by the long-term interaction of geological bodies and external forces in the earth, while the slope topography of highways is formed by high filling or deep digging on the basis of natural landforms. In addition, the road construction methods are different under different topographic and geomorphic conditions, and the change ~~of~~ in topography is also different. No matter the slope formed by nature, or the engineering slope formed by the construction of a highway, they all have the characteristics of improving ~~the~~ stability by reducing the body's potential energy, and they all have the trend of evolving to ~~the~~ flat land. Therefore, topography and geomorphology are ~~one~~ some of the conditions for slope diseases. The subgrade is built in areas with large fluctuation, such as slope bottom, depression, valley, etc., where water flows together, if the subgrade drainage system is not perfect, it will lead to subgrade subsidence and collapse disease.

(2) Geological structure: Geological structure refers to the folding, fracture, cleavage, and other structures formed under the action of internal external forces of rock and rock, which is one of the conditions that affect slope stability and cause slope diseases. The scale and form of large-scale slope damage are often controlled by geological structure. The stronger the geological structure is, the more developed the fracture of rock mass, and the lower the corresponding rock strength index, the more likely it is to cause the slope disease. In areas with poor geological conditions, karst, pits, or ancient landslides are distributed under the subgrade. Under the action of continuous driving load, the original bad geological conditions are further stimulated, resulting in subgrade subsidence and collapse diseases.

(3) Formation lithology: Because the mechanical properties of different rock and soil bodies are different, their contribution rates to the development of slope diseases are also different. For example, the slope composed of soil, silty, or sedimentary rocks has relatively low mechanical properties and is more prone to slope diseases. The slope which is composed of metamorphic sedimentary rocks is relatively less prone to slope diseases because the strength of rock mass is increased by metamorphism. The slope composed of magmatic rock has higher mechanical strength, so the slope damage is the least. However, the slope composed of metamorphic magmatic rocks has more slope diseases due to the deterioration

of metamorphism and lower mechanical properties than the parent rocks. Special soil includes artificial fill, soft soil, expansive soil, loess, frozen soil,and so on. The composition of artificial filling is chaotic and the uniformity is poor. In the construction ofasubgrade, if the foundation with special soil is not properly treated, it is easy to cause the subsidence and collapse of thesubgrade.

(4) Meteorology and hydrology: Water has two kinds of dynamic and physicochemical effects on slope and subgrade. The mechanical action includes dynamic water pressure, hydrostatic pressure, and weight gain effect of water on slope and subgrade. The physical and chemical action mainly refers to the weakening effect on the structural plane and the softening effect on the slope and the subgrade. Hydrology includes surface water, groundwater, and rainfall. When ahighway is constructed, Bridges are usually built along the surface water system, so the influence of surface water subgrade disease is small. Groundwater and rainfall are the main factors that affect the embankment disease. Heavy rain or long continuous rainfall will greatly affect the stability of theslope, thus leading to ~~the~~ embankment disease.

(5) Human activities and other triggers: Human activities can damage the evolution of natural slopes. During the construction of the highway, the terrain along the road will be changed, the natural slope along the road will be transformed into a cut, or the original foundation will be filled to form an embankment slope. ~~In order~~To make the engineering slope along the expressway reach a stable state and put itinto normal operation, some slope protection measures will be applied to it. If the protection measures are not perfect, the slope will still have diseases under the action of internal and external factors, which will affect the road capacity. When constructing asubgrade, improper selection of subgrade fill, unreasonable filling method, and insufficient compaction will bury hidden dangers for subgrade subsidence and collapse disease. Subgrade subsidence and collapse disease may occur under the comprehensive action of driving load and water. Unreasonable and imperfect drainage systems will ~~make~~ cause a lot of rainwater infiltration~~,~~and ~~also~~ cause subgrade subsidence and collapse disease.

2. EXISTING SUBGRADE DISEASE CLASSIFICATION METHODS

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2.1Classification method of slope disease

At present, the classification of slope has been studied internationally for a long time. However, due to the complexity of the material composition, formation lithology, deformation mechanism, and damage mode of the slope, as well as the differences in the practical problems and cognition degree to be solved by different researchers in different regions, there are great differences in the principles and indicators of classification. The existing classification methods of slope damage can be divided into two categories according to the number of indicators used: single-factor index classification or multi-factor index classification.

(1) Single-factor index classification method of slope diseases: It refers to the classification based on the single characteristics of slopes. Dana[4] initially classified landslides into three categories: debris flow, rock landslide, and soil diffusion, which laid the foundation for subsequent landslide classification research [5,6]. At present, the classification method of slope by foreign scholars Varnes has been widely recognized, which divides the types of slope instability into six categories: collapse, tipping, sliding, lateral expansion, flow, and compound movement [7]. Fu Chuanyuan [8] first carried out research in this area, and later many scholars proposed a variety of slope classification methods based on different purposes [9-11]. According to the development mode of collapse, Hu Houtian [12] divided collapse into five basic types: toppling collapse, sliding collapse, bulging collapse, tensile collapse,and discontinuous collapse. Jiang Deyi et al. [13] put forward an engineering geologi-

cal classification method of slope suitable for expressway engineering on the basis of summarizing the investigation results of expressway engineering slope. The undeformed slope is divided into rock slope, soil slope, and soil rock slope. Cheng Yonggang [14] analyzed 75 landslides on 8 expressways built in Shanxi Province and divided them into rock and soil landslides according to their material composition, and then subdivided them into six subcategories: shear bed, bedding, broken rock landslides and loess, clay, and accumulated soil landslides. Li Anhong et al. [15] divided bedding cutting slope into 8 categories according to different failure modes: bedding sliding damage, bedding slip-tension damage, wedge sliding instability damage, slip-bending damage, slip-compression tension damage, sliding span damage, bending and tension toppling damage of steep rock formation, and plastic flow along the bottom soft rock stretching damage. Li Song [16], ~~on the basis of~~based on elaborating the influencing factors and development and evolution process of post-earthquake collapse geological hazards, summarized the formation mechanism of post-earthquake highway slope collapse geological hazards as fracture-slip type, fracture-toppling type, fracture-buckling type, and fracture-dislocation type. Based on the unique development characteristics of loess slopes in northern Shaanxi, Peng Jun et al. [17] divided them into six damage forms: spalling type, caving type, terrace type, tipping type, sliding type, and caving type. According to the damage drive mechanism, it can be divided into four kinds: stress drive, joint drive, disturbance drive,and mixed drive.

The above classification method only uses a single factor index, which plays a good guiding role in slope investigation and treatment design to a certain extent. However, because there are too few control indicators, some key characteristics of the slope are difficult~~be reflected~~ to reflect, so its practical application is also limited.

(2) Multi-factor index classification method of slope disease: single factor method considers the result of landslide instability damage, that is, the damage mode or instability mechanism, and only pays attention to the result rather than the cause of the result. Multifactor classification focuses on causes, that is, internal and external factors such as material composition and structural characteristics (internal causes) and rainfall and excavation (external causes). Therefore, multi-factor taxonomies are more specific and provide more guidance for actual projects. For example, according to the actual situation of road slope engineering in Fujian, Liao Xiaoping [18] classifies the soil-like road red slopes in this area into four categories according to material composition, genetic mechanism, and slope structure characteristics: residual soil slope, weathered soil slope, foreslip deposit slope, and complex structure slope, and analyzes their corresponding deformation and damage mechanism. Based on the purpose of landslide prediction and prediction, Yang Shiyi [19] used three indexes of landslide bank slope structure, stratigraphic lithology characteristics, and deformation monitoring curve to classify the landslides along the Yangtze River. Fan Honghai [20] analyzed the influence of geological conditions of theslope, rock mass structure type, lithology combination, geometric size, and the position relationship between slope strike and seismic fault on the dynamic response characteristics of theslope, and divided cut slopes into 6 categories, 18 sub-categories and 54 sub-categories. Ma Baocheng [21] divided slope water damage into five categories according to disaster factors and damage types: slope erosion, slope erosion, slope rainfall instability, and slope drainage ditch system, and protection engineering water damage. Song Shengwu [22] proposed a unified classification system of slope based on slope stability evaluation on the basis of influencing factors such as stratum lithology, the development degree of theweak structural plane and its combination with slope surface, theintegrity of rock mass, deformation and damage characteristics, etc., and divided slope structure types into 21 subcategories of 5 categories: massive structure, quasi-massive structure, non-massive structure, fragmented structure, and deformation structure.

2.2Classification method of subgrade subsidence and collapse disease

The subgrade is the foundation of pavement, and its quality is directly related to the safety and smoothness of theroad. Subgrade subsidence and collapse disease have a certain degree of concealment, not easy to find, once the disease problem appears, it has reached a very serious degree, usually causing a large loss, and repair difficulty, large engineering amount, high cost. The occurrence and development of subgrade subsidence and collapse disease are related to the engineering properties of subgrade fill, groundwater and surface water, dynamic strength characteristics of soil, driving load, temperature, and its change. The comprehensive effect of various factors will cause subgrade subsidence and collapse disease under the correlation. Subgrade subsidence and collapse of existing roads pose a great threat to driving and safe operation. How to classify and evaluate subgrade subsidence and collapse is of great practical significance to ensure safe operation. To fundamentally solve the problem of subgrade subsidence and collapse disease, the premise is to understand the causes of disease, and development, and change law, in order to find targeted treatment. There isa lot of research on the characteristics and mechanism of subgrade subsidence disease in China. Zhang Minjing [23] took the eastern section of theXuzhou Ring Expressway of theJingfu Line as an example to briefly describe the subgrade diseases caused by poor geological engineering such as liquefied soil, soft soil, expansive soil, karst caves, and goaf. Zhang Quansheng [24] analyzed the causes of subgrade diseases from four aspects: base, geotechnical foundation, subgrade of special soil layer, and bad geological phenomena. According to the survey results of Qinghai-Tibet highway diseases, Chen Jianbing [25] believes that the subgrade diseases of Qinghai-Tibet highway can be divided into low subgrade diseases dominated by symmetrical settlement deformation and high subgrade diseases dominated by longitudinal cracks. Then, the formation mechanism of high subgrade diseases is analyzed. Zhou Dequan et al. [26] summarized the common subgrade disease forms including transverse crack, longitudinal crack, andoverall or local collapse, and analyzed the main causes. Lu Li [27] analyzed five common disease forms of highway subgrade: filling and excavation junction, poor subgrade compaction, jump-off at bridge head, damage to retaining structure, and damage caused by water damage. Based on existing data and research, Bai Liru et al. [28] concluded that the main subgrade disease types of theQinghai-Tibet highway are: uneven deformation subsidence, freeze-heave and thawing settlement and turning, subgrade longitudinal cracking, wave deformation,and subgrade transverse cracking, etc. Huang Yongfei [29] analyzed the characteristics and causes of highway subgrade subsidence and subgrade subsidence in theloess area.

3. CONCLUSION

Subgrade disease classification is one of the hot and difficult topics in the field of subgrade disease research. Through the summary of the current research results, it can be seen that:

(1) From the point of view of the number of classification indicators, the classification index of subgrade disease gradually develops from the initial single-factor index to themulti-factor index. On the one hand, the subgrade disease exposed to engineering practice is becoming more and more complex; on the other hand, the factors leading to the occurrence of subgrade disease are also increasingly complex. Therefore, the classification method of subgrade disease based on multi-factor index will become the future development direction.

(2) From the perspective of attribute selection of classification index, since subgrade disease is usually the result of the joint action of internal and external factors, the selection of classification index of subgrade disease should include both attributes. At present, the best classification methods of slope disease or subgrade subsidence and collapse disease basically include these two attributes. In short, in order to accurately classify roadbed diseases, the

selection of classification indicators should fully consider the internal and external factors affecting the stability of slope and roadbed and the mechanical response of the external causes of slope and roadbed, so as to describe the mechanical behavior of slope and roadbed more accurately and objectively, and then establish a more accurate slope classification system.

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