Review Article

Review of classificationandpreventionof sub-grade defects

ABSTRACT

Subgrade defects 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 defects. For this reason, firstly, subgrade defects are divided into slope defects and subgrade subsidence defects according to the definition. and the existing subgrade defects classification methods are divided into single-factor index classification method and multi-factor index classification method, and through comparison, it is concluded that the multi-factor index classification method is better.Finally, the prevention and control measures of the existing subgrade defects are summarized from three aspects: optimization design, foundation reinforcement and improvement of drainage facilities.This will provide reference and ideas for the classification and prevention of sub-grade defects.

Keywords:Subgrade defects; Slope defects; Classification; Prevention.

1. INTRODUCTION

1.1 Significance of classification andpreventionof subgrade defects

Due to the topographic and geomorphological conditions and geological environment in which subgrade are located, as well as the different combination of their natural factors, such as geology, geomorphology, hydrology and meteorology, as well as the wide variety of engineering scales and construction methods, subgrade tend to exhibit different deformation and damage characteristics [1]. The subgrade defects will be a serious threat to the road safety, and its maintenance and repair costs remain high, to a certain extent, will restrict the local economic construction and development.In order to facilitate the recognition, description and evaluation of subgradedefects, reveal the nature of their deformation and damage, and better prevention and control, it is necessary to classify and study subgradedefects. Many scholars have used different methods to conduct in-depth research on the mechanism of subgradedefects from different angles.The purpose of theclassification of subgradedefects is to analyze and summarize the apparent characteristics and the internal and external factors that induce its instability, to briefly reflect the internal law of similar subgradedefects instability [2]. Scientific and reasonable classification of subgradedefects can not only deepen the understanding of subgradedefects, but also quickly identify the attributes of subgradedefects according to classification characteristics, as the main basis for taking engineering prevention and control measures.Therefore, from the practical point of view of operation management, and disaster prevention and mitigation,the research on the classification and prevention of subgrade defects is a fundamental work of great significance.

1.2 Definition of subgrade defects

Subgradedefects includes slope defectsand subgrade subsidence defects. Subgrade refers to the belt structure built as the pavement foundation according to the route location and certain technical requirements (highway is composed of asurface 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 [3]. Slope defects mainly include landslides, collapse,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 slope are collectively known as landslides, 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. subgrade subsidence defects include subsidence and collapse.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 [4].

2. EXISTING SUBGRADE DEFECTS CLASSIFICATION METHODS

2.1Classification method of slope defects

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 defects: It refers to the classification based on the single characteristics of slopes. Dana[5] initially classified landslides into three categories: debris flow, rock landslide and soil diffusion, which laid the foundation for subsequent landslide classification research [6,7]. At present,Varnes' classification method of slope has been widely recognized, which divides the types of slope instability into six categories: collapse, tipping, sliding, lateral expansion, flow and compound movement [8].In China,Fu Chuanyuan [9] first carried out research in this area, and later many scholars proposed a variety of slope classification methods based on different purposes [10-12]. Jiang Deyi et al. [13] put forward an engineering geological 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 sub-categories: shear bed, bedding, broken rock landslides and loess, clay and accumulated soil landslides.Based on the unique development characteristics of loess slopes in northern Shaanxi, Peng Jun et al. [15] 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.Some scholars have proposed a more detailed classification of a defect. Based on a detailed investigation of the collapse sites of theBaocheng Line and other railways, Hu Houtian [16] divided collapse into five basic types: toppling collapse, sliding collapse, bulging collapse, tensile collapse and discontinuous collapse. According to different failure modes,Li Anhong et al. [17] divided bedding cutting slope into eight categories: 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 [18], 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.

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 to reflect, so its practical application is also limited.

(2) Multi-factor index classification method of slope defects: 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 [19] 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 [20] 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 [21] 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 subcategories and 54 sub-categories. Ma Baocheng [22] 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 [23] 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 the weak structural plane and its combination with slope surface, the integrity 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 defects

The subgrade is the foundation of pavement, and its quality is directly related to the safety and smoothness ofthe road. Subgrade subsidence defectshave a certain degree of concealment, not easy to find, once the defects 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 defects 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 defectsunder the correlation. Subgrade subsidence defectsof existing roads pose a great threat to driving and safe operation. How to classify and evaluate subgrade subsidencedefects is of great practical significance to ensure safe operation. To fundamentally solve the problem of subgrade subsidence defects, the premise is to understand the causes of defects, anddevelopment and change law, in order to find targeted treatment. There is a lot of research on the characteristics and mechanism of subgrade subsidence defects in China.

(1)The single-factor index classification methods: According to the composition of the adverse geology, Zhang Minjing[24]took the eastern section ofthe Xuzhou Ring Expressway of theBeijing-Fu line as an example, classified the subgrade subsidence defects into five categories: liquefied soil, soft soil, expansive soil, soluble hole, and hollow area. According to the deformation mechanism, Chen Jianbing [25]divided the subgrade subsidence defects of Qinghai-Tibet highway into low subgrade subsidence defects dominated by symmetrical settlement deformation and high subgrade subsidence defects dominated by longitudinal cracks, and then analyzed the formation mechanism of high subgrade subsidence defects.According to the forms of deformation and failure, Zhou Dequan [26]divided the common subgrade subsidence defects into three categories: transverse crack, longitudinal crack, whole or local collapse, and analyzed the main causes of the diseases.

(2) Multi-factor index classification method: According to the depth and material composition of the subgrade,Zhang Quansheng[27] divides thesubgrade subsidence defects into four categories: base defects, soil and soil foundation defects, subgrade defects of special soil layer, and bad geological phenomenon defects.According to structural composition and deformation mechanism, Lu Li[28] classified common highway subgrade subsidence defects into five categories: filling and excavation interface, subgrade compaction poor, bridge head jump-off, retaining structure damage and water damage. According to material composition and deformation mechanism, Bai Liru[29] classified the main subgrade subsidence defects of Qinghai-Tibet Highway into five categories: uneven deformation subsidence, freeze-heave and thawing settlement and churning, subgrade longitudinal cracking, wave deformation and subgrade transverse cracking.In order to improve the construction quality of railway engineeringsubgrade, Wang Guodong [30] investigated the loess subgrade defects in Lanwu section of Lanxin Line, analyzed the causes of wet settlement defects, divided the subgrade settlement defects into six types: subgrade settlement, sinkhole, ballast capsule, foundation softening, overturning slurry mud, subgrade shoulder falling extrusion, and put forward the corresponding prevention measures.

2.3 Review of the current state of research

Subgrade defects classification is one of the hot and difficult topics in the field of subgrade defects 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 defects gradually develops from the initial single-factor index to themulti-factor index. On the one hand, the subgrade defects exposed to engineering practice is becoming more and more complex; on the other hand, the factors leading to the occurrence of subgrade defects are also increasingly complex. Therefore, the classification method of subgrade defects based on multi-factor index will become the future development direction.

(2) From the perspective of attribute selection of classification index, since subgrade defects is usually the result of the joint action of internal and external factors, the selection of classification index of subgrade defects should include both attributes. In order to accurately clas-

sify subgradedefects, the selection of classification indicators should fully consider the internal and external factors affecting the stability of slope and subgrade and the mechanical response of the external causes of slope and subgrade, so as to describe the mechanical behavior of slope and subgrade more accurately and objectively, and then establish a more accurate slope classification system.Therefore, the better method to classify subgrade defects is based on multifactorial indicators.

3. MEASURES TO PREVENT AND CONTROL SUBGRADE DEFECTS

3.1Optimization design

Scientific and reasonable design is the basis for guaranteeing the quality and safety of subgrade, therefore, the influence of various factors on subgrade should be considered when designing, so as to make preparations for dealing with various defects. First of all, geological exploration should be in-depth and detailed, and accordingly select a reasonable line, avoiding the dangerous, safety hazards of the section; secondly, according to the site conditions to determine the appropriate subgrade filler, for example: loess subgrade filler can be old loess, can also be used for the new loess, if the conditions allow, priority should be given to the new loess, but can't be mixed, and can even be used to other filler for the replacement of filler[31] ; slope and slope shape of the Design also has a crucial impact, in the design, should consider a variety of factors, determine a reasonable slope and slope shape, in order to ensure the stability of the slope at the same time, reduce the impact of rainfall scour [32]; necessary slope protection is also the focus of the design, in the design can be considered using grass planting, smearing, hammering surface, slurry piece of slope protection, grille protection and hanging network spray anchors, and other means of improving the stability and scour resistance of the slope [33,34]. The design can consider adopting the means of planting grass, hammering surface, slurry masonry sheet protection, grid protection and hanging net spraying anchors to improve the stability and scour resistance of slopes.

3.2 Foundation reinforcement

For highway subgrade, its advantages and disadvantages largely depend on the stability and strength of the foundation. Choose a suitable way to reinforce the foundation to enhance the stability and strength of the foundation, and then reduce the incidence of various defects. Common base reinforcement methods include overpressure consolidation method and chemical consolidation method. Among them, the overpressure consolidation method mainly includes the impact compaction method and the tamping method[31],and the basic principle is to prompt the soil particles to be closely arranged by means of mechanics (shock wave, dynamic pressure, etc.) to achieve the soil base reinforcement; and the chemical consolidation method mainly includes the alkali liquid reinforcement method and the silicification method. At the same time, the replacement filling method[35] is also an important method to improve the stability and strength of the foundation, removing the poor soil layer within the subgrade, backfilling and compacting with stable sandy soil, natural gravel or grey, changing the characteristics of the foundation and improving its deformation resistance and stability. By setting bedding can also improve the water stability of the foundation, general road construction process often set gravel bedding and grey soil bedding to reduce the impact of water on the subgrade. In addition, the reinforcement of loess can also effectively reduce the incidence of disease, such as grey soil compacting, reinforcing (film, rope mesh, geogrid) and driven sheet piles[36,37].

3.3Improvement of drainage facilities

Reducing the interference of water on the subgrade is an important way to protect and reduce the occurrence of defects[38]. According to the hydrogeological conditions, before the construction of the subgrade, scientific planning and design of drainage facilities, drainage facilities should be perfect and reasonable, to ensure smooth drainage, in order to reduce the adverse effects of rainwater and groundwater on the subgrade[39]. Such as on both sides of the highway were set up drainage ditches, dispersal of surface water and rainwater, to avoid highway slopes subject to rainwater scouring; in the road rift valley slopes can be set up at the top of the slope area interceptor ditch, so that you can avoid the impact of rainwater scouring of the slopes, at the same time to set up the corresponding drainage ditch at the bottom of the slope, so that you can drain rainwater in a timely manner, to reduce the erosion of its harm to the subgrade.

3. CONCLUSION

(1) Due to the variety of subgrade defects and the wide range of industries involved, there are a variety of different classification systems, on the one hand, it shows that the classification of subgrade defects is a necessary basic research work for many industries, and on the other hand, it also shows that it is difficult to classify the subgrade defects, and at present, there has not appeared a system of subgrade defects that can be applied to any industry and region.

(2) In the subgrade defects classification system, the classification index is an important factor, and different classification results can be obtained by choosing different classification indexes. For this reason, this paper summarizes the previous research results based on single-factor index classification method and multi-factor index classification method.

(3) The existing methods of prevention and control of subgrade defects are summarized from three aspects:optimization design,foundation reinforcement and improvement of drainage facilities, which can provide certain guidance for the prevention and control of subgrade defects.

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