The Study Status of the Impact of Heavy Axle Load to Shakedown Theory for Road Pavements

Dan LUO

School of Civil Engineering, Chongqing Jiaotong University, Chongqing, 400074, CHINA

Abstract: Not only have the number of heavy vehicles on the rapid growth, but also increases the load of the vehicle，in the early the road to make use of already appeared on the ruts，pits, cracks, subsidence and other damage, leading to pavement life shortened it to cause great social and transport sector economic losses. This paper introduces the concept of shakedown theory, and reviews the research status at home and abroad by shakedown theory. Subgrade damage occurs by plastic creep shakedown behavior into the behavior of incremental collapse stage, and critical stress level is present between the two kinds of behavior. During the study, the common problems they face is how to define the timing of the subgrade soil destruction.

Keywords: Heavy axle load; Subgrade soil; Shakedown theory; Timing of destruction

1. Introduction

In recent years, with the rapid development of China's national economy, the demand for transportation is increasing, China's highway construction has been rapid development. Road traffic situation is undergoing great changes, the highway traffic generally larger, there is a rapid growth not only on the number of heavy vehicles, and vehicle load increases, the axle load is also growing and the general quality of vehicle overloading, the channels of the vehicle, so that the problem of road damage in the heavy traffic of rapid intensification. The emergence of heavy traffic load based on a certain stage of development of operational mechanism of social and economic background of the transportation industry, has its emergence and existence of internal and external causes. In view of this traffic conditions, we should analyze the conditions and laws of their occurrence and development, study the mode of action of its road, take appropriate measures in roadbed pavement structural design and materials and other aspects of the design, rather than blindly counterweight to limit overloading of vehicles，blocking penalty. Otherwise, not only will not solve the fundamental problem, but also to a certain extent, limit the sustainable development of the transport sector. Provisions relating to automotive standard axle load of most countries in the world, all with the actual vehicle axle load changes gradually adjust.

2. The Influence of Heavy Axle Load on Road

High-level highway pavement Structure (mainly asphalt) in use by the combined effects associated with said traffic load conditions, the emergence of different forms of road damage phenomenon. Road in many areas are unable to meet the design life, has emerged in the early use rut, pit , cracking, subsidence and other damage, leading to greatly shorten the life of the road surface, pavement performance while rapid decay, which give society and the transport sector causing great economic losses. subgrade is a support structure, under traffic loads, subgrade soils will significantly permanent deformation, after the performance of a larger settlement and differential settlement workers, and gradually reflected in the road surface, thereby affecting the performance and service life of the pavement structure . subgrade deformation is caused by excessive damage is one important reason, in the total pavement structure deformation, deformation of subgrade accounted for a large part, about 70% to 95%. Subgrade deformation including elastic deformation and plastic deformation of two parts, the plastic deformation of the subgrade soil will cause the plate fracture, so the load on the subgrade soil stability by studying the fold axis, in order to improve the resistance to deformation of subgrade is to improve the whole structure subgrade important aspects of strength and stiffness.

Figure 1 shows the relationship between settlement and loading time when the size of the load change,, seen from Figure 1, the load decreases, the deformation decreases. But changing the load variation of strain did not affect the same curve shape deformation under different loads. When the load value is small, the load increases, the amount of the settlement is almost no change, and when the load reaches a certain value, the load increases will be significantly increased the amount of the settlement, but then continue to increase the load, but no settlement will

HK.NCCP

International Journal of Intelligent Information and Management Science
ISSN: 2307-0692, Volume 5, Issue 4, August 2016

be a substantial increase in. Therefore, beyond a certain limit load have great influence on subgrade settlement.
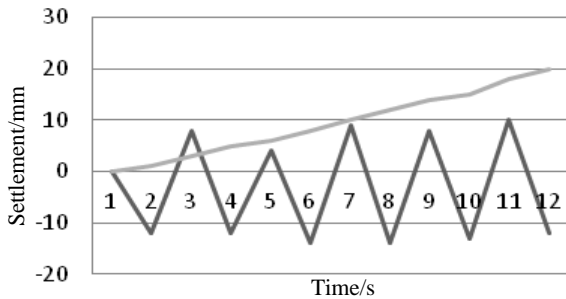

Figure 1. The influence of loadsize of subgrade settlement

3. The Concept of Shakedown and Critical Stress Level

3.1. Shakedown

shakedown concept was originally used to describe the mechanical behavior of metals subjected to repeated cyclic stress. shakedown refers to plastic deformation behavior in a particular structure repeated loads generated will stabilize after a limited number of loads, and within safety limits, the body does not produce structural damage. However, the stress state is continued to a certain extent, the plastic deformation as the load times will continue to accumulate and showed an unstable state, until the structure due to excessive plastic deformation of the damage so far. shakedown concept may be described in the behavior of materials under cyclic load, wherein the common behavior perfectly elastic behavior, elastic shakedown behavior, plastic behavior, plasticity and creep behavior of incremental collapse behavior [1-4].

3.2. Critical Stress level

Stress level is defined as the axial stress during cyclic loading triaxial test shear strength 1/2 and the resulting static soil destruction under the same conditions when τcu ratio that SL = (σd/2) /τcu. At high stress levels, subgrade soil will cause excessive plastic deformation; stress level is small, after a certain number of traffic load, subgrade soil will reach a stable equilibrium state, that is, the road is no longer cumulative plastic deformation increases, subgrade soil under certain stress level for the elastic behavior, or the slow accumulation of plastic deformation. In the cycle repeated loads, the deformation behavior of subgrade is characteristic, can be divided into different ranges (for stable and unstable behavior), within these ranges, there is a critical stress state is shakedown limit . When the stress state in which the earth when shakedown limit or less, the performance of shake-down or elastic plastic or plastic creep shakedown shakedown behavior; and the state of the soil in which the stress on

shakedown limit, the number of load cycles increases, plastic rapid accumulation of strain and shear damage.

4. The Research Status at Home and Abroad

Melan [5-8] as early as 1936 to carry out the research of pavement structure. The early 1970s, the early 1980s began to permanent deformation of subgrade as an important factor leading to road damage and rutting generated gradually permanent deformation break out from the total variation, semi-quantitative study of permanent deformation of subgrade soils and pavement structure behavior, constitutive model was established to predict permanent deformation of the pavement structure, and when the regression equation considering the resilience modulus. shakedown theory was first settled by the Melan [9-13] for elastoplastic and kinematic hardening material derived obtained. shakedown theory refers to the plastic deformation of the structure under repeated loading a specific load, generated will stabilize after a limited loads, and within safe boundaries, and the structure does not cause damage.

Thereafter, with the rapid development of computers, the development of the theory of plasticity and shakedown gradually improved, Sharp et al [14] to discuss this issue and numerical analysis and computer simulation, and analysis is no longer confined to the subgrade soil, but for the entire road system architecture, multi-stability theory thus be applied to pavement life and shake-down limit load estimates.

1984 Sharp et al [15] for the first time shakedown theory into the research of the pavement structure for mechanical behavior characteristics of the pavement structure, creating a new field for the mechanical characteristics of the pavement structure analysis.

Seed et al [16] studied the compressive strength and deformation characteristics of clay under cyclic loading in 1955 to 1967. Early prototypes of the indoor unit is mechanically load the load change, the versatility of the instrument is restricted, during the test does not allow researchers to easily change the parameters or tests to accurately measure all of the data. Due to limitations of these devices by the majority of research is to serve the total deformation .Although there are some results in order to evaluate rebound, rebound deformation also studied, but no permanent deformation will break out from the total deformation. These analyzes can only establish cyclic loading and deformation of the qualitative relationship.

Yangshu Rong [17] found that the critical stress axis poor subgrade with water content decreased with the increase; rise with the confining pressure increases. If the stress - strain relationship, it must be able to rely on complex dissipate the growing phenomenon to the exact timing of the determination to settle the critical state occurs. By the

HK.NCCP

International Journal of Intelligent Information and Management Science
ISSN: 2307-0692, Volume 5, Issue 4, August 2016

shakedown theory it shows that an increase in the collapse phase behavior, subgrade soils are often a large amount of plastic strain, while in the stable state, the accumulated plastic strain situation will stabilize. Subgrade damage occurs by plastic creep shakedown behavior into the behavior of incremental collapse stage, and critical stress level is present between the two kinds of behavior.

Since the subgrade soil lead to rutting damage morphology and traditional foundation works soil sliding failure of different forms, therefore, it can not be the traditional civil engineering 15% or 20% of the plastic strain to define the timing of the destruction of subgrade. ince 1960, many scholars deefinition of working under critical stress level cyclic loading and triaxial repeated load test has to be discussed. During the study, the common problems they face is how to define the timing of the subgrade soil destruction.

Larew etc. [18] 29 - think the damage occurred in the strain rate under repeated loading, strain rate) began to increase.

Gaskin et al. [19] In discussing the behavior under cyclic load Sydenham sand, indicate the type of damage perpetual deformation and destruction, that the time of damage occurrence strain rate is increased to the maximum.

Brown et al. [19] The effects of over-saturated silty clay and different compaction degree of destruction, that the subgrade soil in some areas is close to saturation, analyze test results available to the saturated effective stress concept.

Werkmeister et al. [17] for two types granular soils were different axle differential stress and confining pressure triaxial repeated load tests and found that granular soils under cyclic load process also has a shakedown behavior can be observed shakedown behavior of the plastic, plastically deformed latent cumulative and incremental collapse behavior of three types of permanent strain and to determine the range under different confining pressure and axial differential subgrade soils combined stress critical stress state according to their behavior.

Mitchell and other findings show that damage is due to the occurrence of soil under cyclic loading pore pressure continues to increase, and finally developed enough to fall within the effective stress path is defined by a static triaxial test failure envelope region , resulting in effective stress increases and decreasing load times, increasing the pore pressure and initial stress state and stress level related to the size, the greater the initial confining pressure, pore water pressure greater, there are a few samples the effective despite the stress path failure envelope falls outside the area but still had destroyed.

Raymond etc. for Leda clay were Unsaturated Cyclic loading tests under different stress levels, test results show that the number of permanent strain increases the load gradually increased, and the stress level of 0.53 for the sector. Permanent strain can be divided into two dis-

tinct types: ① when the stress level is greater than 0.53, the permanent strain increases rapidly until shear stress damage occurred; ② when the stress level is less than 0.53, the cumulative permanent strain remained stable.

Liao Huarong [13] combined with shakedown and energy dissipation theory point of view, to determine the water content the the different critical stress level of red clay under cyclic loads, and to determine the water content the different subgrade red clay under cyclic loading the failure envelope envelope. In addition, the critical stress level and confining pressure has a close relationship. For cohesive soil, except Brow n et al. [32-33] have been explored for overvoltage different densities, the remaining majority of scholars in the Discussion of critical stress level is defined to be below a certain confining pressure.

5. Conclusion

With the transportation industry to flourish ,the concept of shakedown of subgrade soil came into being, as has put forward the concept of time is shorter, there are to be further studied, the most urgent need to address is how to define the timing of the subgrade soil destruction

References

[1] Sharp R W, Booker J R. Shakedown of Pavement sunder Moving Surface Loads[J] . Journal o f Transpor -tat ion Engineering , 1984 , 110(1): 1-14.

[2] Seed H B , CHAH C K , MONISMITH C L. Effects of Repeated Loading on the Strength an d Deform at ion of Compacted Clay[J] .H RB Proceeding s , 1955 , 34: 541 - 558.

[3] Seed H B ,Chan C K. A Effects of Stress History and Frequency of Stress Application on Deformation of Clay Subgrades under Repeated Loading[J] . H RB Proceed ing , 1958 , 37: 555 -575.

[4] XIE Kang, PAN Qiuyuan. Layered Foundation one-dimensional consolidation theory under arbitrary loading [J] Journal of Geotechnical Engineering, 1995, 17 (5): 80--85.

[5] Zhong Huihong, HUANG Mao-song, Wu Shiming, etc.. Study on deformation of soft clay under cyclic loading [J]. Journal of Geotechnical Engineering, 2002 , 24(5): 629 - 632.

[6] HUANG Yu, Stephen F Brown, Clenn R Medowdl. Flexible pavement under cyclic loading roadbed deformation dynamic coupling analysis (English) [J]. Journal of Geotechnical Engineering,2001, 23(6) : 757−762.

[7] HUANG Yong. Heavy traffic road axle load conversion validation formulas, Shanxi traffic technology, 1989

[8] Xu Jianping, Xie Weiping. Paths of Stress Under Typical dynamic loads and dynamic analysis of soil [J] Huazhong University of Science and Technology: Urban Science, 2002, 19 (2): 42-45.

[9] LI Shizhuang. Subsidence due to the vehicle composite subgrade [J] Changchun Institute of Technology: Natural Science Edition, 2002, 3 (2): 26 - 28.

[10] XU Gan-cheng, XIE Ding-yi, ZHENG Ying-ren. Elastoplastic modeling for cyclic stress strain behavior of saturated sands[J]. Chinese Journal of Geotechnical Engineering, 1995, 17(2): 1−12.

HK.NCCP

International Journal of Intelligent Information and Management Science
ISSN: 2307-0692, Volume 5, Issue 4, August 2016

[11] Wang Jianhua, YAO Minglun. Undrained cyclic properties of soft clay elastoplastic simulation [J] Journal of Geotechnical Engineering, 1996, 18 (3): 11-18.

[12] YANG Shurong. Rebound and plastic behavior patterns and subgrade soil under repeated load Construction [D] Chinese Taipei: National Institute of Civil Engineering, Central University, 2002.

[13] LIAO Huarong. Research on mechanical behavior and predicting model of subgrade red clay under repeated dynamic load[M. S. Thesis][D]. Guangzhou : Sun Yat-sen University , 2004.(in Chinese)

[14] Tang Liansheng, Zhang Qinghua, Li Jingze, and so on.Subgrade soil dynamic stress strain accumulation under traffic load.

[15] Ling Jianming, Wang Wei, Wu Hongbo. Research Vehicle Load marshy embankment residual deformation [J]. Journal of Tongji University, 2002 , 30(11): 1 315-1 320.

[16] ZHOU Jian. Elastoplastic study on cyclic strain of Saturated soil [J]. Chinese Journal of Geotechnical Engineering, 2002, 22(4): 499-502.

[17] WERKMEISTER S, DAWSON A R, WELLNER F. Permanent deformation behavior of granular materials and the shakedown concept[C]//Proceedings of 80th Annual Meeting, Transportation Research Board, Washington D.C: [s. n.], 2001.

[18] MELAN E. Theorie Statisch Unbestimmter Yysteme Ausideal-plastischen Baustoff[J]. Sitzungsberichte der Akademie. Der Wissenschaften in Wien , 1936 , 1: 45-195.

[19] BROWN S F. 36th Rankine lecture: soil mechanics inpavement engineering[J]. G éotechnique, 1996, 46(3):381-426.