PROFESSIONAL ENGLISH IN TRANSPORTATION ENGINEERING

交通运输工程系列教材

交通运输工程专业英语

主编 赵娅丽

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内容提要

本书根据历年来同济大学交通运输工程学科专业英语教学的实际情况，参考已出版的国外专业读物编写而成。主要内容包括：道路工程（第1章），交通工程（第2章），交通信息工程（第3章），物流工程（第4章），轨道工程（第5章），铁建工程（第6章）。

本书可供从事交通运输工程专业英语教学的教师，交通运输工程专业大学生、研究生及交通运输领域相关人员使用。

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前　　言

近年来，我国高校不断加强对外开放的力度，国际间的学术交流活动也日渐频繁，这些都为包括交通运输工程领域在内的大学本科生、研究生提供了优越的英语实践条件。一方面，大学生、研究生的阅读和会话水平大幅度地提高；另一方面，学生们在各自专业领域与国外学者的直接交流范围，以及他们对最新知识和最新动态的需求，都远远超出现有教材的容量。在交通运输工程领域，本科生学习的主要目的是在掌握基础理论知识基础上，尽可能扩展视野，了解国内外交通运输工程理论与实践的发展现状和前景。在不掌握基本专业英语知识的情况下，本科生在初涉英文专业材料时，阅读和理解上会有较大的难度，亟需专业英语学习的辅助来跨越这一门槛。为此，根据历年来同济大学交通运输工程学院专业英语教学的实际情况，参考已出版的专业读物，我们编写了这本教材，希冀能通过一个学期的系统性入门教学，尽可能满足当今大学生对专业英语知识的渴求。

本书有如下几方面的特点：

（1）选材尽量涉及目前交通运输工程领域的各个专业和方向，包括道路工程、交通工程、交通信息工程、物流工程、轨道工程、铁建工程等，力求教授学生比较全面的交通运输规划领域的知识。

（2）本书所有的文章均节选自国外相关教材、杂志、著作等，力求内容全面，并能提供最新的、有代表性的研究成果。

（3）本书尽可能扩大阅读中的词汇量，重点培养学生灵活使用英文单词、自主开拓阅读空间的能力。

（4）每篇文章后面附有注释和练习，辅助学生理解和掌握。

本书选材比较宽泛，篇幅较多。从体例上，以专业为单元，每个单元包含5～7篇文章。在分专业的专业英语教学中，除对本专业单元内容进行精讲之外，可选择其他专业的部分篇章作为泛读材料，主要培养阅读速度，扩大知识面。本科教学过程中以专业词汇精讲为主，以专业材料理解能力培养为辅。研究生可以此教材为基础，更进一步地进行大量专业英语材料的阅读、理解，培养自主查找相关资料、撰写英语专业文章的能力。因此，该书是交通运输专业英语领域的入门教材。

本书由同济大学交通运输工程学院统一规划，副院长严作人教授、教务科张纪京老师负责全面组织，出版社的编辑也提出了很多建设性意见，为本书的出版奠定了基础。本书由赵娅丽统一组织编排。其中道路工程部分由丛林负责编写，交通工程部分由赵娅丽负责编写，交通信息工程由曾小清负责编写，物流工程由朱晔负责编写，轨道工程由徐行方负责编写，铁建工程由刘丽波负责编写，全书最后由赵娅丽统稿。本书可供从事交通运输工程专业英语教学的教师，交通运输工程专业大学生、研究生及交通运输领域相关人员使用。

编　者

2006年12月于同济大学

CONTENTS

CHAPTER ONE

ROAD ENGINEERING

Unit 1

Traffic Analysis

There are many inputs to the road design process. These inputs include: estimates of traffic, environmental considerations, and assessments of the material properties of all of the components of the pavement structure including estimates of material variability and responses to environmental factors. Another consideration is the selection of the degree of design reliability required for a given facility. A freeway may require a higher degree of reliability in the design estimate than a secondary road given the relative sizes of the investments and the cost of future maintenance. *This unit discusses traffic design inputs in detail. Included is a summary of available information to assist the prospective user or developer of the mechanistic-empirical design procedures.*[1]

Traffic

The mechanistic-empirical approach requires that traffic input be transformed into a simplified representation of the complex loading process to which pavements are subjected. It is possible, however, to consider the following seven traffic factors in design: ① tire and axle configurations; ② contact pressures; ③ vehicle speeds; ④ anticipated number of loads in each weight category; ⑤ distribution of traffic during the day and throughout the year; ⑥ distribution of traffic across lanes of multi-lane highways; and ⑦ lateral distribution of traffic within specific traffic lane.

The most desirable solution would be to have this data available for the specific highway to be designed. Alternatively, traffic data contained in national, statewide, or local traffic surveys may have to be utilized if data for the specific highway is not available. This will be discussed subsequently.

To estimate damage attributable to specific traffic, it is necessary to establish the correspondence between traffic repetitions and stress applications developed at some critical point in the layer which may be damaged.[2] Thus, the lateral placement and distribution of traffic among lanes of a multi-lane facility must be determined.

Lane Distribution of Trucks

The correspondence between the number of vehicle passages within the design lane and the number of load repetitions at some critical points, is dependent on the tracking of the vehicles using the lane. Taragin has shown that the center of the average truck is located within 0.2 feet of the center of a 12-foot wide lane and that about 75 percent of the observed trucks maintained a lateral position within one foot of the center of the lane. He also notes that little difference occurs in this pattern on slight curves and that placement on two- and four-lane highways is approximately the same.

Fordyce and Packard have examined the variation in the lateral location of the wheels of a typical truck. Fig. 1-1 shows this lateral distribution. *If the smooth curves shown in this figure are assumed to represent a normal distribution of the center of the loaded area about the center of the wheel path, a standard deviation of about nine inches will yield the frequency distribution shown for the tail of the curve.*[3]

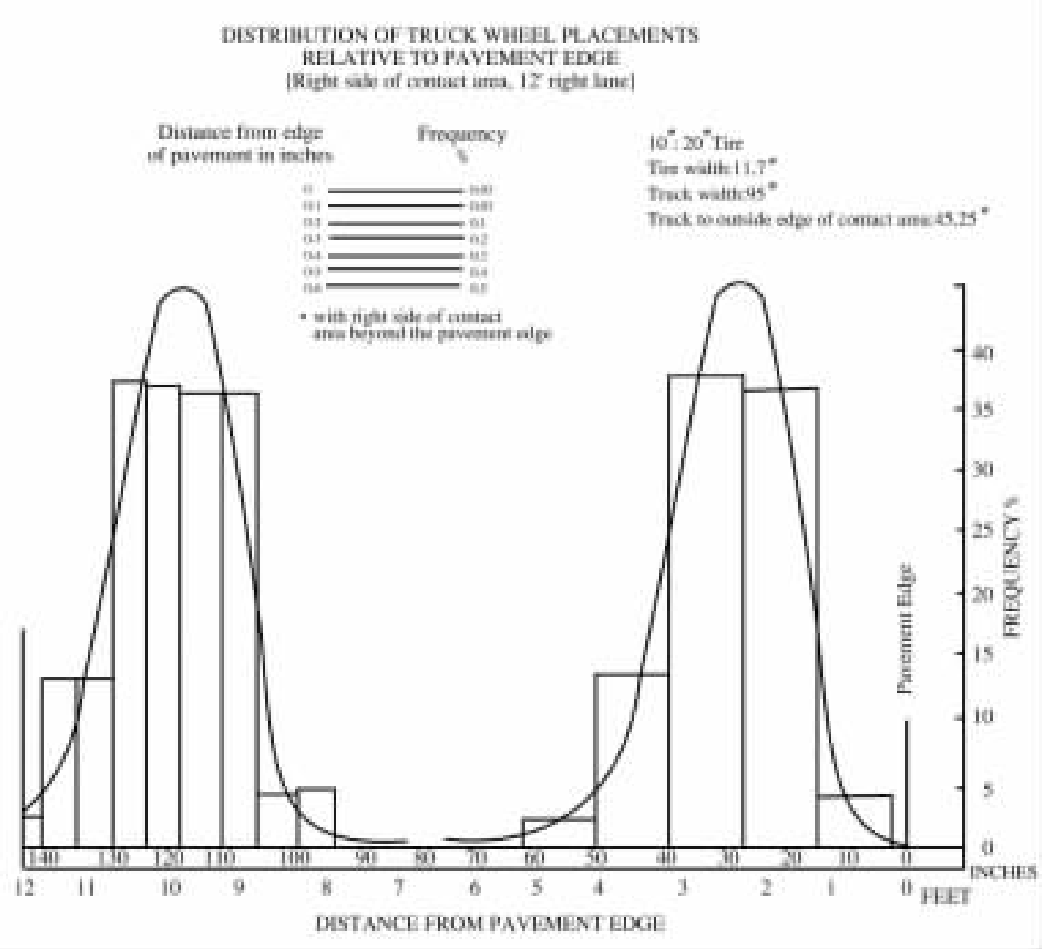

Fig. 1-1　Lateral distribution of trucks within a traffic lane

(After Fordyce and Packard)

For asphalt concrete pavements, analyses indicate that the stress level at the underside of the asphalt concrete layer is relatively constant over the section from outside to outside of the tires. If we now assume that a typical dual tire spacing is 14 in. center to center of the tires and that each of the tires has an effective load radius of 4 in, we can see that the center of the wheel path* is strained near its maximum for every passage of a dual tire within 11 in. of the center of the wheel path. Assuming the normal distribution of lateral locations based on Fordyce and Packard's curve, this indicates that about 80 percent of all passages will result in this strain level at the center of the wheel path. Since the dual dimensions assumed above might be considered as minimum spacing, it is reasonable to assume that each passage of such a load will result in near maximum strain at the critical location. The remainder of the wheel load passages will result in some lesser strain level at the critical location in the design lane.

From this argument one can see that it is not unduly conservative to use a one-to-one relationship between wheel load passages in the design lane and load repetitions at the center of the wheel path for asphalt pavements. More sophisticated treatment of the lateral location variation does not seem justified for this type of pavement, at least when one considers the accuracy that can be expected from the estimates of traffic that will be used.

The situation for jointed concrete pavements is however considerably different. Substantial field data and analysis results indicate that the critical fatigue location is at the slab edge. This is where transverse cracks initiate when the slab is fully supported (when a serious loss of support occurs at the joint, corner breaks or diagonal cracks may occur first before transverse cracking). The other potential critical location is in the wheel path at the transverse joint. Fatigue damage studies, however, have shown that this is rarely the critical fatigue point.

The lateral distribution of truck wheels is approximately normally distributed with a standard deviation of about 10 inches. For design, the number of repetitions of the critical (edge) stress is approximately the proportion of truck wheel loadings within 6 inches of the slab edge. The mean distance from the slab edge to the outside of truck dual tires should be estimated from visual observations of truck traffic on similar portland cement concrete highway pavements in the local area. The proportion of wheel loads within 6 inches of the edge can then be easily computed using the normal distribution.

In the absence of locally specific data, an estimate of the mean distance from the slab edge to the outside of dual truck tires can be made using the following general guidelines.[4] On highways with unpaved shoulders, 8-foot-wide lane would be, on the average, 24 inches from the slab edge. However, considerable evidence indicates that on highways with paved shoulders and no lateral obstructions, trucks travel closer to the slab edge, with the mean distance being between 12 and 21 inches. A 1956 Bureau of Public Roads study of lateral truck distribution on two-lane concrete highways showed a mean distance of 11

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* Note: Considered to be the critical location for fatigue in asphalt concrete.

inches, while a 1975 study by Emery of truck traffic on rural four-lane Interstate highways showed a mean distance of 16 to 18 inches.

Vehicle Speed

To define the stiffness characteristics of materials in the pavement section, an estimate of vehicle speed is required. Time of loading has a significant influence on the stiffness characteristics of asphalt paving mixtures. Barksdale, Brown, and McLean have provided some guidelines to relate the time of loading required for estimates of or laboratory assessments of stiffness characteristics as related to vehicle speed.

McLean's results illustrate the time of loading for an equivalent square wave load pulse for vertical compressive and horizontal stresses as a function of depth. Barksdale's results are superimposed for comparison. It should be noted that the differences between the two many be due in part to the fact that Barksdale's calculations were based on a triangular load shape as compared to the square shape used by McLean. In spite of the differences, the results are within a relatively close range and provide a good indication of the time of loading that should be used in laboratory testing.

Notes

[1] This unit discusses traffic design inputs ...**这一单元具体讨论与交通相关的设计参数。其中包括对未来用户和力学经验中路面设计程序开发者的有用信息**。

[2] To estimate damage attributable to specific traffic, it is necessary to ...**要估计某类交通荷载造成的损伤,需要建立重复交通荷载与可能损坏结构层、临界点所受应力之间的相互关系**。

[3] If the smooth curves shown in this figure are assumed to...**如果如图中所示的光滑曲线是描述行车轨迹中心中央负载面积的正态分布,那么大约九英寸的标准偏移也服从图示曲线的频数分布**。

[4] In the absence of locally specific data, an estimate of...**当没有当地的具体资料时,可以参照下面一般的方法估计从路面边缘到轮胎外侧的平均距离**。

Exercises

(1) What are the inputs to the design process?Choose one to explain how it influence the design process.

(2) Which traffic factors should we consider in pavement design?Which do you think is the most important, why?

(3) Where are the two critical fatigue locations for jointed concrete pavements?

Unit 2

Soils and Granular Materials

Soils, being naturally occurring materials, have more variable properties than the man-made mixes, either bound or unbound, which are used in the pavement structure. *The mechanical properties of subgrades, whether cut or fill, have an important bearing on the design of the pavement since the latter is essentially required to protect the former from excessive stresses.*[1]

Granular materials used in the base and subbase layers have constituents which are controlled to some extent, but the nature of current British specifications is such that density checks, for instance, are not used and wide variations in mechanical properties are possible. Tighter control is affected in many countries, particularly where the granular base is only covered by a modest thickness of bituminous material and its behavior is therefore the controlling factor in the performance of the pavement.

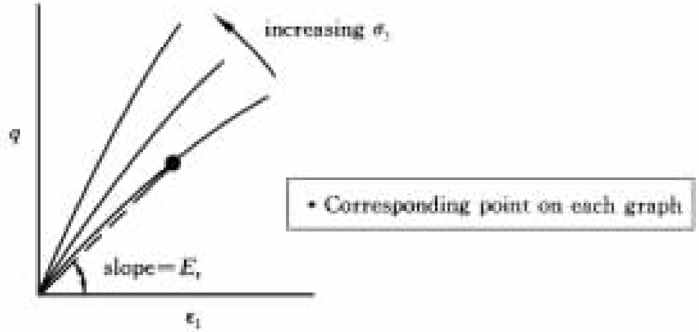
In view of the variability of soils and granular materials, it is not surprising that their mechanical properties are not so conveniently characterized in predictive forms as bituminous material. None the less, general behavior patterns and the important variables affecting them have been determined and these are reviewed below.

Non-linearity

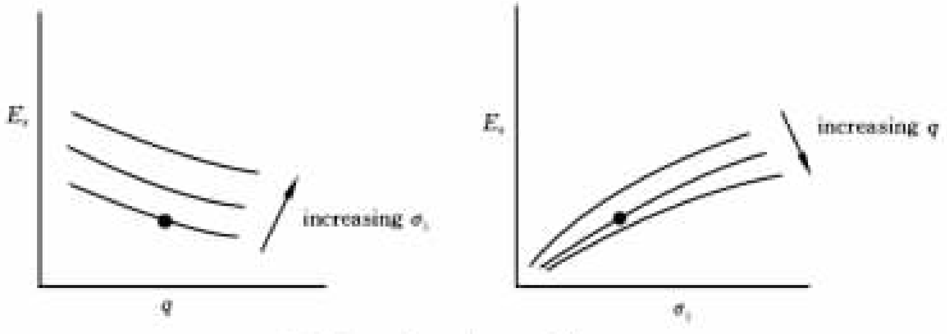
The stiffness or elastic modulus of bituminous materials was shown to depend primarily on temperature and loading time. Stress level was not discussed as a variable of particular importance for pavement design, since bituminous materials are essentially linear elastic under dynamic conditions except at high stress levels when there is some decrease in stiffness. This behavior is very much a function of the properties of the bituminous binder. Unbound aggregates and soils, on the other hand, generally contain water in their pore spaces and its influence is rather different since it cannot directly offer resistance to shear deformation like a bituminous binder. The most important difference in response between this type of material and bituminous ones is that soils and granular materials are markedly non-linear. Their stress-strain curves are indeed curves and the resulting resilient modulus of elasticity is very stress-dependent.

The non-linearity of soils and granular materials can be represented in a simple general way by the curves in Fig. 1-2. Consider a repeated load triaxial test in which a series of specimens, or even a single specimen if the stresses are not too high, are subjected to various magnitudes of repeated deviator stress under various static confining stresses. Eq. (1-1) indicates that the resilient modulus (E_r), being the secant modulus, will be affected both by deviator stress (q) and confining stress (σ_3)

$$E_r = f(q, \sigma_3) \tag{1-1}$$



(a) Basic stress-strain relationship



(b) Stress dependent modulus

Fig. 1-2 General representation of non-linearity for soils and granular materials

More generally it can be said that the modulus depends on both *shear stress* ($q/2$) and *mean normal stress* (p)[2] which is related to *confining stress*[2]

$$P = \frac{\sigma_1 + 2\sigma_3}{3} = \frac{q}{3} + \sigma_3 \tag{1-2}$$

The relative influence of these two basis types of stress depends very much on the material and the conditions of test and these will be discussed in the following sections.

The non-linearity of cohesive soils in terms of the stress dependence of resilient modulus is of the form shown in Fig. 1-3. *These tests were on samples of saturated silty clay having various consolidation stress histories from normally consolidated to an over-consolidation* *ratio of* 20.[3] The relationship is of the form

$$E_r = \frac{K}{\left(\frac{q_r}{\sigma_3'}\right)^n} \tag{1-3}$$

Where σ_3' = initial effective confining stress;

q_r = cyclic deviator stress;

K and n = constants which depend on the soil type.

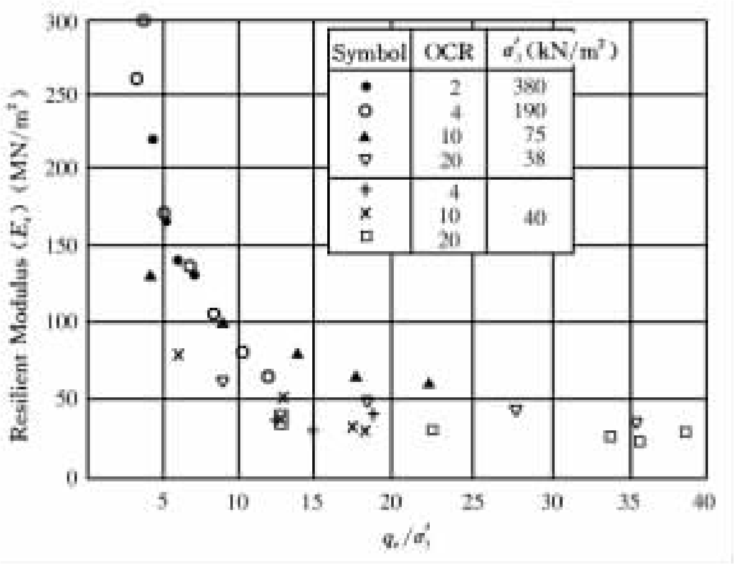


Fig. 1-3 Resilient modulus of a saturated silty clay as a function of stress

The development of permanent strain under repeated loading depends not only on the applied deviator stress (q) but also on the stress history of the soil. The contrasting behavior of a silty clay when normally consolidated and when heavily over-consolidated. Compacted, partially saturated soils show behavior rather similar to that of the normally consolidated case.

Several investigators have reported a threshold deviator stress (q_r), or zone of stress, above which the material will eventually fail, and below which the sample will not fail. Furthermore, the shear stress at failure under repeated loading has been shown to be about 70% of that under conventional static undrained test conditions.

For heavily over-consolidated clays a well defined failure condition is not reached, but strain levels are about twice as high as in the normally consolidated case.

The pavement design process requires detailed information relating permanent strain to applied stresses for the detailed deformation prediction procedure outlined in another unit. A potential aid for obtaining this kind of data more easily is represented by the creep test as is the case for bituminous materials. Hyde and Brown have shown that reasonable predictions of permanent strain rate under repeated load conditions can be obtained from creep tests.

Alternatively, Monismith et al, have suggested a framework which could be used if repeated loading facilities are available. They showed that the permanent strain (ε_p) after a given number of cycles was related to deviator stress by a hyperbolic equation of the form

$$q_r = \frac{\varepsilon_p}{l + m\varepsilon_p} \tag{1-4}$$

where l and m are constants which depend on the soil type and possibly the suction or effective stress. Furthermore, the build up of permanent strain during repeated loading was shown to obey a simple exponential law

$$\varepsilon_p = AN^b \tag{1-5}$$

where N is the number of stress applications, A and b could be experimentally determined.

The subgrade stresses below well designed pavements are likely to be low and, therefore, the question of failure is unlikely to arise.

Permanent strains could also be small and the relationship of Eq. (1-4) gives a method of predicting such strains from data produced in tests at higher stress and strain levels which would be more reliable.

Granular Materials

Resilient Strain

For the purposes of this discussion, granular material embraces both the unbound aggregate used in base and subbase construction and noncohesive soils. As for cohesive soils, frequency of loading has no effect on resilient strain and an equilibrium level of strain develops under sub-failure conditions after a reasonable number of load applications.

The non-linearity of granular materials is typically represented by the results. This shows a well defined relationship of the form

$$E_r = K_1 \theta^{K_s} \tag{1-6}$$

Where θ = sum of the principal stresses which for triaxial test is $\sigma_1 + 2\sigma_3 = q + 3\sigma_3$

K_1, K_s = constants which depend on the material.

More recent research has shown that the resilient behavior is much more complex than Eq. (1-5) suggests but that under conditions well removed from failure this equation seems appropriate. It has been incorporated into non-linear analysis procedures for pavement structures using either finite elements or layered systems. With reference to Eq. (1-1) the resilient modulus of granular materials has been found to depend strongly on normal stress but to be relatively independent of shear stress level.

Poisson's ratio has been shown to depend on the principal stress ratio or the ratio of deviator stress to mean normal stress ($p = \theta/3$) with a better defined relationship resulting from the use of effective stress rather than total stress. Its magnitude increases with increasing q_r/p but a value of 0. 3 is considered appropriate for simple design calculations.

The precise form of the stress-dependent equations for resilient modulus and Poisson's ratio depends on the aggregate grading, density, particle shape and texture and moisture *conditions.*[4] In general, higher density produces higher resilient modulus and the dependence on normal stress is greater with rounded aggregate than angular.

The role of moisture in granular materials is not well defined but it appears to be limited to its effect, via suction or pore pressure, on effective stress. Results in terms of effective stress show that moisture content has little effect on the constitutive equations.

The likely response of a granular material in a pavement is complicated by the fact that the density which can be achieved depends on the stiffness of the supporting material. Furthermore, its non-linearity and lack of tensile strength results in very low or zero modulus towards the bottom of the layer because of the tendency for tensile stress to develop in this zone. Wave propagation testing of various combinations of granular material and subgrade soil has indicated that for design purpose a modular ratio between the two layers of about 2.5 is appropriate for linear elastic analysis. This reflects the effective modulus of the granular layer and the effect which it has on other layers. It is not suitable for use in calculating the stresses and strains in the granular layer itself for which purpose a non-linear analysis should be used, and this is discussed at the end of this unit.

Permanent Strain

A permanent strain illustrates the importance of adequate drainage and that equilibrium strains develop after some 10^4 cycles in drained tests unless the stress level approaches a failure condition. For poorly graded, single size material, which is not recommended for road construction, permanent strain continues to build up even after very large numbers of cycles. The value of this equilibrium strain depends on the ratio q_r/σ_3 and, since drainage has been allowed, σ_3 is in fact the effective stress. Similar results are obtained for both static cycles confining stresses if the former is equated to the mean value of the latter.

Barksdale tested a range of granular materials and aggregate-soil mixes from which it is apparent that the percentage of fines should not exceed that required to provide high density, if low deformations are required. He also established the validity of a hyperbolic stress-strain curve of the type discussed above for cohesive soils. In order to compare his materials in the context of the pavement, Barksdale used a "rut index" which was defined as the sum of the permanent strains at the centre of the top and bottom halves of the granular layer multiplied by 10^4. The figures are based on the strains after 10^5 load repetitions in a repeated load triaxial test under stress conditions dictated by a non-linear analysis of the pavement structure. Typical stresses could probably be developed for standard types of structures and environments to obviate the need for analysis on every occasion.

Notes

[1] The mechanical properties of subgrades, whether cut or fill, have an important bearing on the design of the pavement since the latter is essentially required to protect the former from excessive stresses. **此处**,"the latter"**指**"the man-made mixes","the former"**指**

"soils"。**不管是路堑还是路堤，路基的力学性质都与路面的设计有着重要的关系，因为本质上要求后铺材料防止土基承受过大的压力**。

[2] shear stress **剪应力**，mean normal stress **平均主应力**，confining stress **围压**。

[3] These tests were on samples of saturated silty clay having various consolidation stress histories from normally consolidated to an over-consolidation ratio of 20. **这些实验以一些饱和粉质粘土为样本，这些土样的固结应力历史各不相同：从正常固结土到** 20%**的超固结土**。

[4] The precise form of the stress-dependent equations for resilient modulus and Poisson's ratio depends on the aggregate grading, density, particle shape and texture and moisture conditions. **回弹模量和泊松比的应力非线性关系与集料级配、密度、颗粒的形状和纹理以及湿度状况有关**。

Exercises

(1) What determines the stiffness or elastic modulus of bituminous materials? And what does the resilient modulus of granular materials depend on?

(2) How different is the shear stress at failure under repeated loading to that is under conventional static undrained test conditions?

(3) Is single size material not recommended for road construction? Why?