INTERPRETATION OF ASPHALT MATERIAL DESIGN PARAMETERS

Atis Zarins*, Viktors Haritonovs, Juris Smirnovs*****
Riga Technical University, Department of Roads and Bridges
E-mail: *atis.zarins@rtu.lv, **viktors.haritonovs@rtu.lv, *** smirnovs@mail.bf.rtu.lv

ABSTRACT

The current situation in road design practice shows that there exists an inconsistency in using and defining some asphalt material parameters. Such inconsistency is due to the introduction of EU standards for materials while leaving the design methods unchanged. In order to find possibilities to adapt the correct modern test methods for asphalt material parameters such as deformation modulus used in road pavement design procedures, the research and theoretical grounds analysis was performed. Current research establishes that after introducing EU standards for road material requirements instead of the former GOST, road engineers were faced with the fact, that EU materials no longer conform to the former design procedure. Some of them start using other design methods different from the previously used GOST based VSN (Russian) pavement design procedure. However, both practices have not been ensured with appropriate design parameters applicable for the used procedures. The main source of inconsistency as stated above is non-compliance of the defined road pavement materials with parameters used in design procedures and, for instance, defined basing on GOST. As a result, it leads to the improperly designed pavement structures and possibly can result in significant losses for the national road industry. This paper presents the interpretation of four point bending test results and the possibility to use them in the most widely used pavement design procedure – VSN. Four point bending tests were performed on AC11 asphalt mixture with conventional (dolomite, quartz sand) and non conventional (steel slag, dolomite sand) aggregates.

Key words: dolomite aggregate, asphalt concrete, permanent deformations, fatigue resistance

INTRODUCTION

In order to find possibilities to adapt the correct modern test and assessment methods for asphalt material parameters, such as a deformation modulus used in road pavement design procedures, the research and theoretical analysis and justification were performed. Current research establishes that after introducing EU standards for road material requirements instead of former GOST, road engineers were faced with the fact, that EU standards for materials no longer conform with former design procedure. Some of them started using other design methods different from previously used GOST based VSN (Russian) pavement design procedure. However, both practices have not been ensured with appropriate design parameters applicable for used procedures. The main source of inconsistency as established is non-complying of defined road pavement materials with parameters used in design procedures and, for instance, defined basing on GOST. As a result, it leads to the improperly designed pavement structures and possibly can result in significant losses for national road industry.

This paper presents the interpretation of four point bending test results and the possibility of their acceptance for use in still mostly used pavement design procedure - Soviet Union flexible pavement design instruction (VSN 46-83, 1985). Four point bending tests were performed on AC11 asphalt mixture with conventional (dolomite, quartz sand) and non conventional (steel slag, dolomite sand) aggregates.

Currently used pavement design philosophy in Latvia, as well as in other Baltic countries is based on former Soviet regulations VSN 46-83 established in the ‘70s of the last century. This design approach includes theoretical justification built on consequences following from the theory of plasticity of composite materials. The theory considers lower semi space as subsoil working in appropriate design conditions and upper semi space – as designed pavement structure, considered as a homogenous formation. No or very little modifications in the used design methodology have been made since this time, however essential changes appear in the used construction technologies and materials, as well as in actual traffic loads.

The same regulation is being used in Russia and most of the other former Soviet republics. There were, however, some essential modifications made. In this context the actual status of pavement design methodology and used parameters are analyzed in this research.

OBJECT OF DISCUSSION

The modulus of deformation is one of the main road pavement parameters used for the theoretical evaluation of a designed structure. As defined in the current design methodology the common or equivalent modulus is the parameter, which theoretically estimates the designed pavement structure. Equivalent modulus of deformation is determined according to the used pavement layer parameters. They are - material, thickness of layer, as well as working conditions expected load: - number of standard axle passes, standard load value and character – static or dynamic, moisture and heat conditions. All of these parameters have been determined by tests or theoretically, using technologies and knowledge appropriate of the time when the methodology was developed in the '70s of the last century. The deformation modulus of road pavement can be theoretically obtained using parameters of materials used in pavement structure, or from testing particular pavement structure in situ. In both cases the possible worst working conditions for particular pavement material must be considered, while setting parameters for testing conditions.

Since parameters of elasticity and strength for bituminous bound materials dependent on loading force, speed, and duration it needs to be specified in terms of actual anticipated loading conditions.

As mentioned in the regulations on the design of non-rigid pavements VSN 46-83, the design values of the deformation modulus of asphalt concrete are determined depending on the working temperature and assigned load condition (Телтаев, 2010). This provides the ability to describe the deformation properties of pavement material by means of value – referred to as the modulus of elasticity, according to whether the load is either static or dynamic. It was required to evaluate non-rigid pavements according to the following three criteria:

- by elastic bending of the structure of the pavement;
- by the permitted shear stress in the subsoil of the roadbed and unbound material layers of the pavement;
- allowabale tensile stress in bent surfaces of bound material layers.

The design values of the modules for asphalt materials of pavement in VSN 46-83 were established by results-oriented research for materials, components and technologies available at that time.

As fixed in regulations (VSN 46-83, 1985) modules of elasticity for evaluation of asphalt concrete road surfaces during dynamic loading were derived from the modulus established providing frequency of load applying an uncertain defined in interval 5 - 20Hz and was described as a dynamic modulus of elasticity. According to the above mentioned regulations the modulus was calculated applying parameters measured during a three point bending test with sample 4x4x16cm and the using equation:

$$E_{dyn} = \frac{Fl^3}{4fbh^3} \quad (1),$$

where F – effective load applied to the sample ($F=k_l k_t P$), $b=h$=4cm, l= 16cm – dimensions of sample. Test measurement must be done after 10 - 30 preliminary loading cycles. Design value must be set as mean from at least three samples.

REWIEW OF PROBLEM

There are many opinions in recent publications concerning the methodology of measurement and setting of design values under discussion. The paper presents overview of publications in general from researchers of countries where particular design principles are topical. Professor Teltaev points, that current standardized design parameters vaguely take into account the actual limits of grain content in composition of aggregate, type, content and physical properties of bitumen, volumetric parameters of mixture, mineral filler content and quantitative characteristics of the impact of climatic and mechanical factors (Телтаев, 2010).

Professor Rudenskiy recommend increasing standard design values for those asphalt concrete materials, with lower values of the actual modules of elasticity, but possessing greater deformative properties must be higher than the standard values from VSN 46-83 for respective grades of asphalt concrete (Руденский, 2010). This conclusion is valid, provided that the compared structures are characterized by the same energy of destruction of asphalt concrete. In case of use of asphalt concrete with greater energy of destruction (for example, using of fibrous reinforcing components), the calculated value of the modulus of elasticity also should be higher due to increased durability of asphalt concrete.

A number of researchers point to the importance of mix character and parameters if establishing design parameters of an asphalt material. Professor Teltaev makes a comparison of laboratory tests on dynamic modulus of HMA from (Flintsch at al. 2007) versus those made using standards based on VSN 46-83 and ODN method (ODN 218.046-01, 2001), and concludes that in both cases fixed modules are higher than those used as standard design parameters in VSN 46-83 and ODN 218.046 -01, and they are sensitive to the mix constituents and mix granulometry.

Professor Sibiryakova draws attention to the necessity to revise the set of standard design parameters considering new materials and technologies used in modern road industry (Сибирякова, 2007; Сибирякова, 2008).

Yeo Y. points out that the four point bending test has the added advantage that it provides a uniform stress distribution (Yeo et al., 2011). In contrast, the three point bending test has the maximum stress concentrated locally below the loading point, exposing only a very limited area of the specimen to the maximum loads. Therefore it follows, that the four point test provides more adequate conditions for establishing of design parameters for road pavement material.

TEST METHODOLOGY

Current research includes measuring and evaluation of HMA deformation parameters during a four point bending test. Test samples were made according to the actual technical requirement (National Road Specifications 2012) and compared with results in (Flintsch at al. 2007) and VSN 46-83.

Tests were performed on AC11 asphalt mixture specimens with conventional (dolomite, quartz sand) and non conventional (steel slag, dolomite sand) aggregates. Two reference specimens were prepared containing different bitumen binders

- BND 60/90, which is most frequently applied binder in Latvian road industry, and
- PMB 45/80-55.

One specimen with hard bitumen BND 20/30 was also tested for reference.

Along with reference specimens, four specimens with experimental mix using two above mentioned binders and different combinations of non conventional aggregates were prepared and tested for stiffness loss and elasticity parameters. All tested specimen mixes were compound and prepared according to granulometry requirements set in technical requirements (National Road Specifications 2012). As seen in fig.1, specimens refer to be characterized as fine grained.

Parameters for the four point bending test were set according to the above described assumptions to simulate dynamic axis load and worst pavement working conditions for elastic bending criteria:

- Test temperature - 20 ºC,
- Loading frequency - 10Hz,
- Uniform deformation - 190 μm/m.

RESULTS AND DISCUSSION

Design parameters for bituminous bound material according to methodology VSN 46-83 must be set depending on bitumen viscosity and working temperature for particular criteria, and depending on criteria to be examined. Parameters for dense asphalt mix (AC11) with bitumen used in the test for dynamic loading conditions are shown in table 1. According to ODN 218.046-01, the modulus of deformation for dynamic loading must be determined after making 1000 loading cycles.

It can be seen in fig. 2 and fig. 3 – the modulus after 1000 cycle loss of stiffness is still in progressing phase. Moreover – during design life of pavement structure significantly more than 1000 axle load application cycles are anticipated. And one of assumptions, which the pavement design is based on, is that the pavement is still serviceable at the end of the design period. Thus, it can be concluded that the number of loading cycles are important when establishing a design value of modulus of deformation. Depending on the material, it stabilizes after 300000-400000 loading cycles and corresponds to 60-80% of initial value of deformation modulus. Nevertheless, it is seen in tab.1 that the actual values of modulus for tested specimens are up to two times greater than the standard design values.

If the deformation module values obtained in the tests are set as in the stable interval of the module exchange (after 300000 loading cycles, see. Fig.2, tab 1.), the actual value of the modulus for tested mix AC11 (dense HMA) with bitumen 60/90 are within the interval 3300-3700, for PMB 45/80-55 – 3000-3400. This means, that if using one value for all mixes, it must be considered, that dispersion in this particular case will be 12% and 13% accordingly, that could be unacceptable if considering adequately designed pavement structure.

Table 1

Comparison of deformation modulus (MPa) for different AC11 mixes and with different bitumen binders fixed as standard design value and measured in tests. (T=20 ºC)

Mix and binder type	1000 cycles	300000 cycles	% loss
Dense HMA 60/90 des.value*	1800*	-	-
Dense HMA 40/60 des.value*	2600*	-	-
AC11(60/90) ref.	5000	3700	70
AC11(60/90)comb.	4700	3400	69
AC11(60/90)co-prod.	4700	3300	67
20/30 ref.	6800	3500	65
AC11 45/80-55 (PMB) ref.	4300	3300	73
AC11 45/80-55 (PMB) comb.	3900	3400	84
AC11 45/80-55 (PMB) co-prod.	4300	3000	63

* Design value VSN 46-83 (tab.13. app.3)

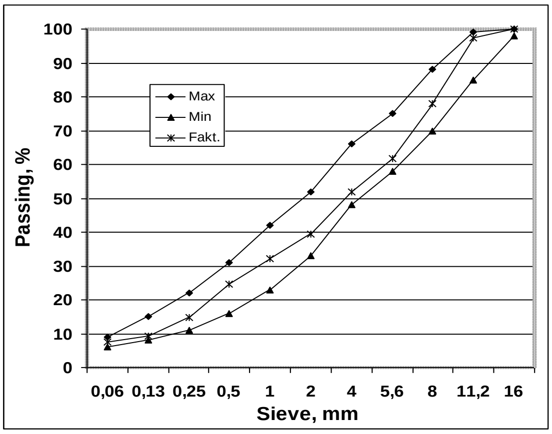

Figure 1. Granulometry of test specimens

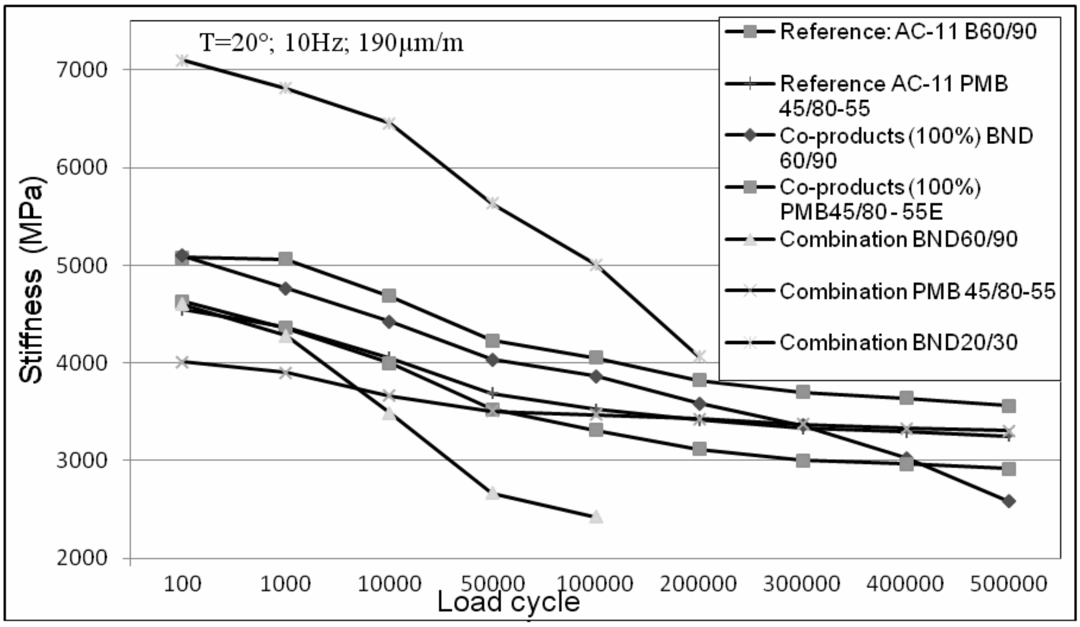

Figure 2. Diagram of stiffness exchange during loading

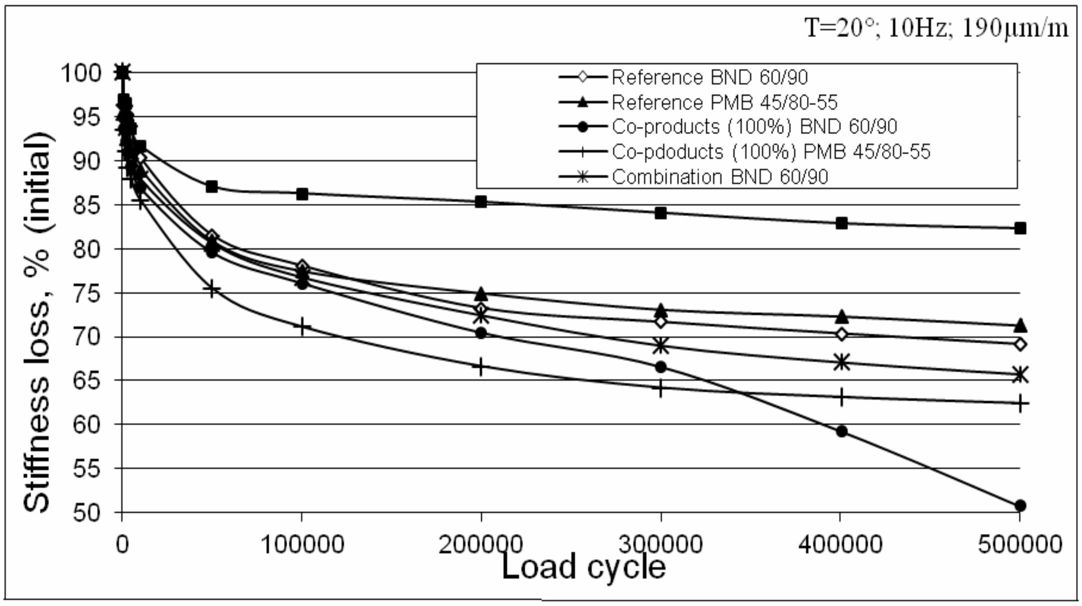

Figure 3. Diagram of stiffness loss evolution during loading

CONCLUSIONS

The four point bending test provides more adequate conditions for establishing design parameters of road pavement material if compared with the tree point bending test.

Measured value of deformation module depends on the number of loading cycles. Therefore the measured design value must depend on the design axle loadings during pavement service life and must be considered in pavement design process.

Asphalt mix made according to the particular standard granulometry and the particular regulations, does not obtain materials with uniform modulus of deformation, therefore for the design purposes it is recommend that the proposed bituminous pavement materials should be tested for establishing a proper design parameter.

Performed tests show significant discrepancy in the properties of test specimens made according to standard specifications compared with properties proposed for design purposes. Therefore, it is recommended to test proposed bituminous pavement materials for establishing proper design parameters.

ACKNOWLEDGEMENT

This work has been supported by the European Regional Development Fund (ERDF) activity No.2.1.1.1. „Atbalsts zinātnei un pētniecībai” (Support for the Science and Research) within project:No.2010/0254/2DP/2.1.1.1.0/10/APIA/VIA A/015.

REFERENCES

Flintsch, G.W., Loulizi, A., Diefenderfer, S.D., Galal, K.A., Diefenderfer, B.K., (2007) *Asphalt Materials Characterization in Support of Implementation of the proposed Mechanistic — Empirical Pavement Design Guide.* Final report. Virginia Transportation Research Council, Charlottesville, Virginia

National Road Specifications, (2012), *Autoceļu specifikācijas-2012,* A/S Latvijas Valsts Ceļi, Rīga. [online]. [accessed on 10.11.2012.]. Available: http://www.lvceli.lv

Yeo, Y**.,** Jitsangiam, P., Nikraz, H., (2011), *Flexural Behaviour Of Cement Treated Crushed Rock Under Static And Dynamic Loads***,** in proceedings of The 7th International Conference on Road and Airfield Pavement Technology, Bangkok, Thailand.

Инструкция по проектированию дорожных одежд нежесткого типа ВСН 46-83 (VSN 46-83), (1985),. Минтрансстрой, Транспорт, Москва (in Russian).

Проектирование нежестких дорожных одежд. ODN 218.046 -01, (2001), , Минтрансстрой, Москва (in Russian).

Руденский, А.В, (2010), Определение расчетных значений модуля упругости асфальтобетона по результатам экспериментального определения фактических значений модуля упругости, *Дороги и Мосты*, № 23, Москва (in Russian).

Сибирякова, Ю., (2007), Экспериментальное исследование некоторых асфальтобетонов под многократной нагрузкой //Транспортное строительство. .№ 4.

Сибирякова, Ю., (2008), Расчетные параметры асфальтобетонных покрытий для проектирования нежестких дорожных одежд , doct. thesis, Moscow, .

Телтаев, Б.Б., (2010), Анализ расчетных значений модуля упругости асфальтобетонов, Дорожная техника №10, , St. Petersburg.