ASSESSMENT OF ASPHALT MATERIAL DEFORMATION MODULUS FOR PAVEMENT DESIGN PROCEDURE

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Abstract. In order to found possibilities adapt the correct modern test and assessment methods for asphalt material parameters such as deformation modulus used in road pavement design procedures, the research and theoretical basement analysis was performed. Current research fixes that after introducing of EU standards for road material requirements instead of former GOST, road engineers were faced with fact, that EU standards for materials no more conforms with former design procedure. Some of them starts using other design methods different from previously used GOST based VSN (Russian) pavement design procedure. However both practices have not been covered with appropriate design parameters applicable for used procedures. Main source of inconsistency as fixed is non-compliance of defined road pavement materials with parameters used in design procedures and, for instance, defined on GOST basement. As result it leads to the improperly designed pavement structures and possibly can result in significant looses for national road industry. This paper presents the interpretation of four points bending test results and possibility of acceptance for use them in still mostly used pavement design procedure -VSN. Four points bending tests were performed on AC11 asphalt mixture with conventional (dolomite, quartz sand) and non conventional (steel slag, dolomite sand) aggregates.

Keywords. Asphalt concrete, four points bending test, permanent deformations, fatique resistance.

INTRODUCTION

Current road design practice in Latvia, as well as in some other countries, which use former GOST standards, shows that there exists inconsistency in using and defining some asphalt material parameters. Such inconsistency is due to introducing EU standards for materials while leaving design methods unchanged. In order to find the 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 basement analysis was 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 materials no more conform with former design procedure. Some of them start 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 points 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 points 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 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 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 other former soviet republics. There, however, some essential modifications were made. In this context the actual status of pavement design methodology and used parameters are analyzed in this research.

1 OBJECT OF DISCUSSION

The modulus of deformation is one of the main road pavement parameters used for theoretical evaluation of designed structure. As defined in the current design methodology the common or equivalent modulus is the parameter, which theoretically estimates designed pavement structure. Equivalent modulus of deformation is determined according to 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 and 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 – the ‘70s of the last century. 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 are dependent from loading force, speed, and duration it needs to be specified in the terms of really 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 is 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 design parameter – referred as the modulus of elasticity, according to whether 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 subsoil of roadbed and unbound material layers of the pavement;
- permitted tensile stress in bended 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 modulus established providing frequency of load applying uncertainly defined in interval 5 - 20Hz and was described as dynamic modulus of elasticity. According to these regulations the modulus was calculated applying parameters measured during three points bending test with sample 4x4x16cm and using equation:

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

were: F – effective load applied to the sample ($F=k_l k_t P$),
$b = h = 4$cm and
$l = 16$cm – 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.

2 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 weekly 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 recommends to increase the standard design values for those asphalt concrete materials, with lower values of actual modules of elasticity, but possessing, at the same time, greater deformative properties. They 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 a asphalt material. Professor Teltaev comparing the laboratory tests on dynamic modulus of HMA from (Flintsch at al. 2007) with those, made according to standards based on VSN 46-83 and ODN regulations (ODN 218.046-01, 2001), and concluded 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 set of standard design parameters considering new materials and technologies used in modern road industry (Сибирякова, 2007; Сибирякова, 2008).
Yeo points, that the four points bending test has the added advantage that it provides a uniform stress distribution (Yeo et al., 2011). In contrast, the three point bending has the maximum stress concentrated locally below the loading point exposing only very limited area of the specimen to the maximum loads. Therefore it follows, that four points test provides more adequate conditions for establishing of design parameters for road pavement material.

3 TEST METHODOLOGY

Current research includes measuring and evaluation of HMA deformation parameters during four points bending test. Test samples were made according to 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

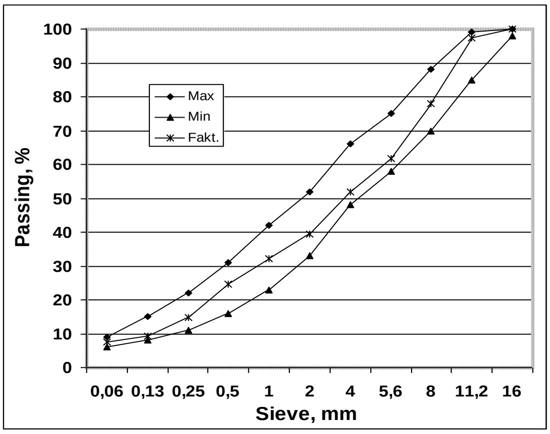

Fig. 1. Granulometry of test specimens

requirements (National Road Specifications 2012). As it can be seen in fig.1. - specimens refer to be characterized as fine grained.

Parameters for four points 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.

4 RESULTS AND DISCUSSION

According to methodology VSN 46-83, design parameters for bituminous bound material 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 binder used in the test for dynamic loading conditions are shown in table 1. According to ODN 218.046-01, modulus of deformation for dynamic loading must be fixed at 1000 loading cycles.

Table 1. Comparison of deformation modulus for different mixes (T=20 ºC)

Mix and binder type	Modulus of deformation (MPa)		% loss
	after 1000 cycles	after 300000 cycles	
Dense HMA 60/90 design value*	1800*	-	-
Dense HMA 40/60 design value*	2600*	-	-
AC11(60/90) ref.	5000	3700	70
AC11(60/90) comb.	4700	3400	69
AC11(60/90) co-prod.	4700	3300	67
AC11 (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)

As it can be seen in fig. 2 and fig. 3, after 1000 cycles 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, on which pavement design is based on, is that pavement is still serviceable at the end of design period. Thus it can be concluded that the number of loading cycles are important when establishing 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, as it is seen in tab.1. actual values of modulus for tested specimens are up to two times greater than standard design values.

If deformation module values obtained in tests are set as in stable interval of module exchange (after 300000 loading cycles, see. Fig.2 and tab.1.), the actual value of 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.

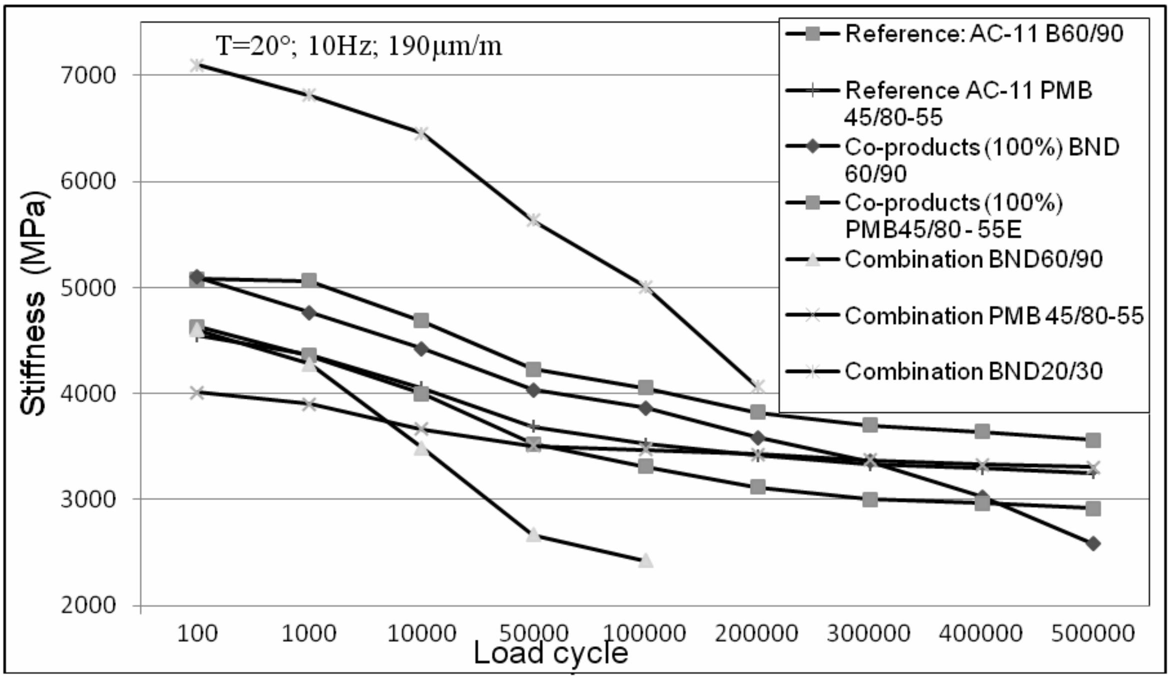

Fig. 2. Diagram of siffness exchange during loading

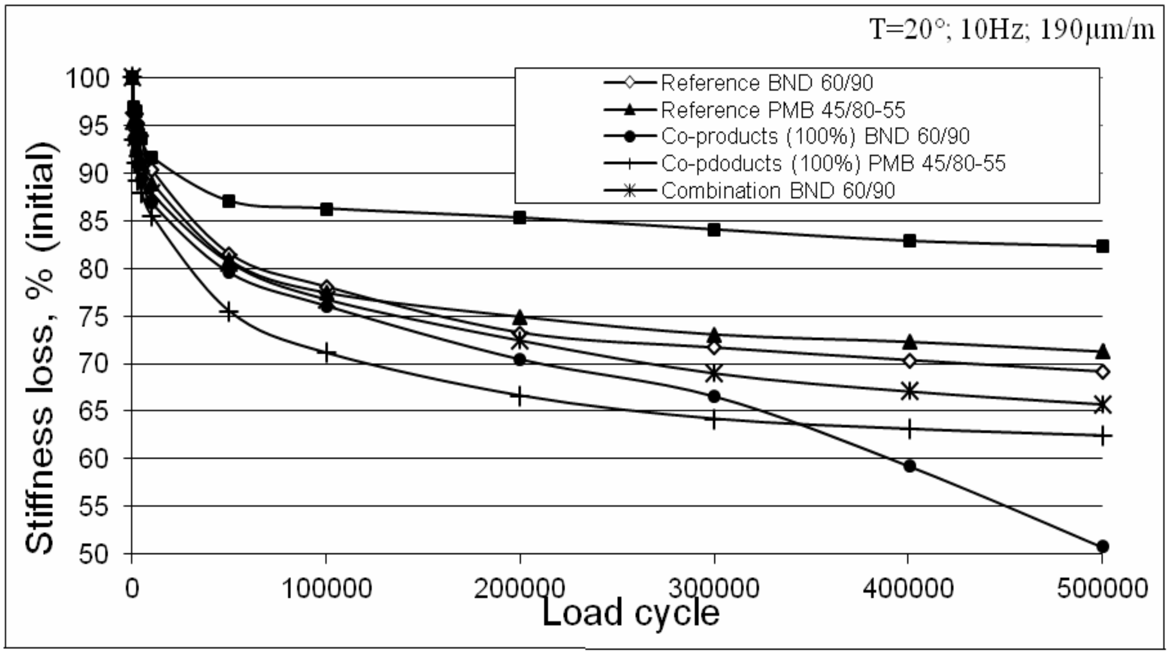

Fig. 3. Diagram of stiffness loss evolution during loading

5 CONCLUSIONS

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

Measured value of deformation module depends on number of loading cycles. Therefore measured design value must depend on 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 do not get materials with uniform modulus of deformation, therefore for design purposes it is recommend that proposed bituminous pavement materials should be tested for establishing proper design parameter.

Performed tests show significant discrepancy in 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.

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