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TESTING OF ASPHALT-CONCRETE WITH A SPHERICAL PUNCH

The application of a spherical punch for determination of basic deformation and strength properties of asphalt-concrete in laboratory and field conditions is substantiated. The proposed method of assessment of deformation and strength properties of asphalt concrete makes it possible to speed up the assessment of quality of pavements construction and increase the reliability of the assessment, since comparison of indices for three types of mixes is supposed to be performed.

Keywords: spherical punch, deformation and strength properties, asphalt-concrete, bitumen, modulus of elasticity.

Introduction

At present time new methods of calculation of road structure are introduced in regulatory design documentation. The methods involve possibility of accumulation of residual deformations during designing and calculation of road pavement. The methods take into account elastoplastic properties of asphalt concrete.

The methods require new devices to control deformation and strength parameters in the stages of designing, construction and operation.

In available regulatory documentation there is certain discrepancy between indices of properties which characterize asphalt concrete as material for road construction and those required characteristics which are used when calculating non-rigid road pavements.

The most important of the discrepancies are that asphalt concrete considered as a road construction material is characterized by the temperature of preparation and laying, fineness of grain, density, water saturation, swelling and strength at temperatures of 0, 20 and 50 ^{0}C. However, when calculating the structure of road pavements, the basic estimated characteristic are modulus of elasticity at static and dynamic loading at different temperatures, bending strength, internal friction and adhesive action. These indicators are determined by additional methods. Averaged values obtained on the base of statistical processing of the results of tests of different compositions of asphalt concrete mix are used as estimated values. In either case, static and dynamic circuits of sample tests differ essentially from the real work of asphalt concrete in pavement.

Strength indices of asphalt concrete in laboratory conditions are determined on standard concrete kerns, but this method does not involve asphalt concrete normalization by deformation characteristics. Deformation characteristics of asphalt concrete, moduli of elasticity and tensile strength in asphalt concrete bending were determined on beams. The method of flat punch pressing in the sample is used to determine asphalt concrete modulus of elasticity at elevated temperatures.

In full-scale tests moduli of elasticity of actual structures are determined under static loading transmitted to the rigid punch of diameter 33 cm or measuring bending under car wheel, dynamic loading apparatus being used. The methods determine modulus of elasticity on pavement surface. The moduli of isolated layers are determined recalculating in accordance with the standards.

Coefficients considering actual working conditions of road pavement are introduced to compare data obtained. The available methods do not allow rheological properties of asphalt concrete to be fully characterized.

In this connection Department of Design of Automobile Roads and Bridges has analyzed application of asphalt concrete strength indices determination using different punches. The studies have shown that it is advisable to have data on maximum bending as well as on outline of deflection bowl in the place of loading. The data make it possible to determine the values of maximum curvature or minimum radius of curvature, tensile stresses. As a result, the method of determination of strength and deformation indices by spherical punch pressing was developed, test devices being made [1].

The method is based on determination of deformation and strength properties of elastic half-space [2]. However, in actual conditions asphalt concrete works as elastoviscoplastic material. The elastoviscoplastic properties of asphalt concrete under spherical punch pressing will be represented in the ratio of elastic δ and residual $\ell_{ocm.}$ deformations. Different ratio of mineral material particles can often be observed. Therefore, value of deformations in different points of pavement will significantly differ under static loading of the punch. This weakness can be reduced to a minimum by stepwise cyclic loading of the spherical punch in one test point. In the case of repeated action of constant load on the spherical punch half-space residual deformations constantly accumulate. The intimate mating of the punch to the asphalt concrete surface is ensured, the formed sphere minimizes influence of material inhomogeneity on the results of the test. The lack of residual deformations at the last loading cycles allows asphalt concrete to be considered as elastic half-space.

Based on theoretical treatment of spherical punch application the pressure has the maximum value (1.5 p_{cp}) in the centre of the tangency area; the pressure becomes zero on the circle of contact with surface. Pressure distribution diagram is the surface of hemispheres, which is closer to the tension distribution from the car wheels.

The spherical punch of radius 63.5 mm with maximum loading 200 kg s were used to determine deformation and strength properties of asphalt concrete and asphalt concrete pavements. For punch with such parameters full-scale determination of deformation and strength properties of the top layers of pavement, value of insertion and average pressure on the punch surface are limited by active zone of elastic half-space in depth no more than layer thickness.

For example, for fine-grained and sand asphalt concrete (the thickness of the layer 4,5-5 cm) the depth of punch insertion L=2 mm, radius of impression a=15.81 mm, active zone 47.43 mm. For coarse-grained asphalt concrete (the thickness of the layer 6-7 cm) depth of insertion ℓ=3 mm, radius of impression a=19.28 mm, active zone 57.86 mm (Fig.).

In laboratory conditions determination of deformation and strenthg properties is performed on standard cylindrical samples, for sand and fine-grained asphalt concrete h=71.4 мм, for coarse-grained asphalt concrete d=h=101 mm. Active zone over horizontal.component is limited by the zone of 31.62 mm from the centre of load application for fine-grained and sand asphalt concrete, 38.56 mm for coarse-grained asphalt concrete. Therefore, active zone is limited by the examples sizes, and the results of sample and pavements tests will have high convergence.

The method makes it possible to determine the stresses, the angle of internal friction and the adherence for asphalt concrete both in laboratory and in full-scale testing. The determination is performed without pavements destruction and at different temperatures.

The reasons of shear deformations, if any, can be efficiently found out, as well as ways of shear stability increase.

The main concern of road organizations is to obtain detailed and reliable information on road-service quality, compliance of actual properties of roads with road safety requirements, as well as with requirements to the planning, distribution and use of financial resources for road maintenance, repair and reconstruction, optimization of road works programs.

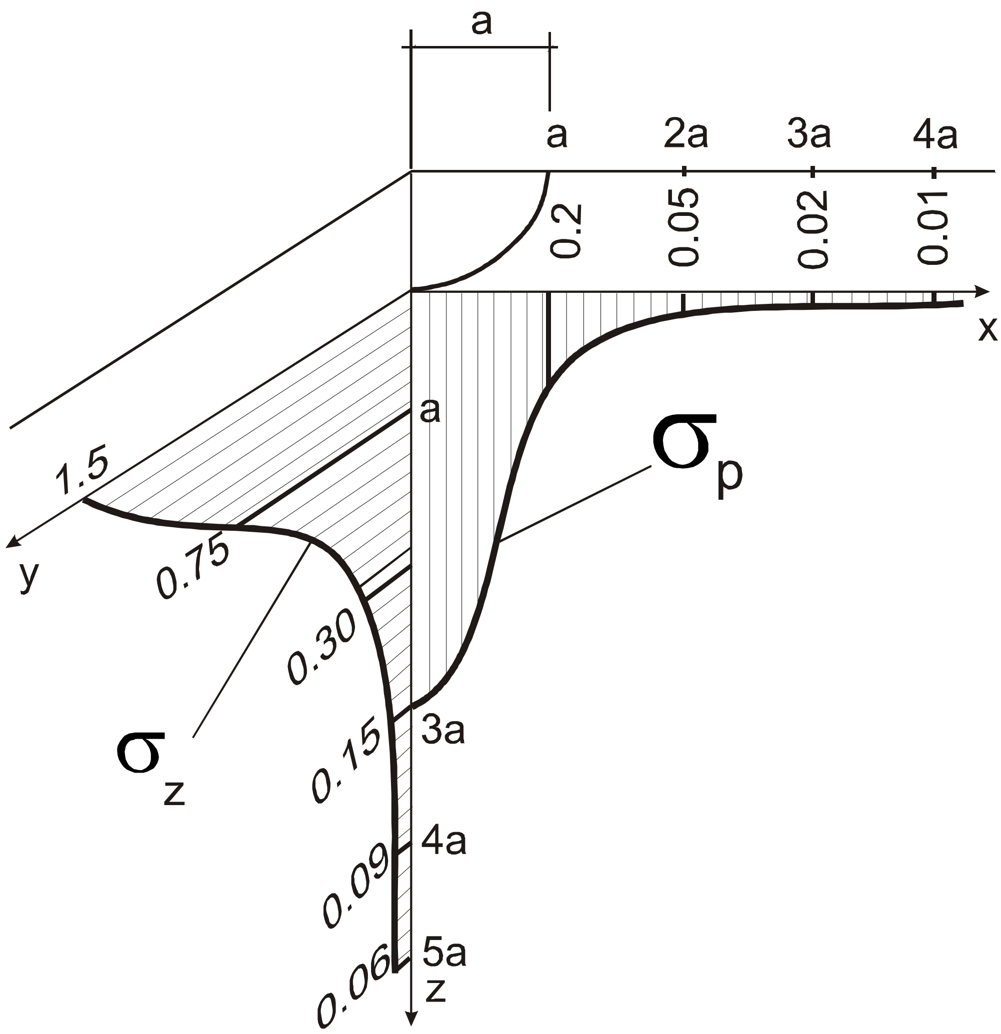

Fig. Tension distribution (parts of P_{cp}) under the influence of spherical punch

The fine-grained asphalt concrete mixes were investigated to assess the use of spherical punch method for determination deformation and strenthg properties at different compaction (30.35 and 40 MPa) and bitumen content (5; 5.5 and 6 %).

The following parameters were determined by the method of spherical punch pressing at cyclic loading [2]:

- steady-state stresses at which material works in elastic state;
- the number of loading cycles before reaching the steady-state stresses;
- static and estimated moduli of elasticity;
- angle of internal friction;
- adherence between the particles.

The results of the tests by the method of spherical punch pressing are tabulated, the indices of results at standard tests being bolded.

Table

Indices of physical-mechanical
and deformation properties of asphalt concrete
in relation to bitumen content

Property	Unit of measurement	Notation	Indices of properties at bitumen content, %		
			5.0	5.5	6.0
Density	g/cm^3	γ	**2.413**	**2.419**	**2.409**
Water saturation	%	W	**1.599**	**1.285**	**0.915**
Swelling	%	H	**0.0**	**0.04**	**0.02**
Deformation and strength indices at 20 ^{0}C					
Compression strength	MPa	R_{20}	**3.42**	**4.15**	**2.6**
Steady-state stresses	MPa	σ_{y20}	4.19	4.41	4.04
Static modulus of elasticity	MPa	$E_{ст}$	374	464	428
Estimated modulus of elasticity	MPa	E_p	2260	2605	2475
Angle of internal friction	degree	φ_{20}	31.68	32.49	36.32
Adherence	MPa	C_{20}	0.57	0,58	0.46
Poisson ratio	-	ν	0.33	0.34	0.35
Deformation and strength indices at 50^{0}C					
Compression strength	MPa	R_{20}	**1,32**	**1.5**	**1.3**
Steady-state stresses	MPa	σ_{y20}	2.58	2.75	2,61
Static modulus of elasticity	MPa	$E_{ст}$	209	211	200
Estimated modulus of elasticity	MPa	E_p	1548	1555	1506
Angle of internal friction	degree	φ_{20}	46.59	51.17	47.51
Adherence	MPa	C_{20}	0.18	0.16	0.18
Poisson ratio	-	ν	0.35	0.34	0.34

End of Table

Property	Unit of measurement	Notation	Indices of properties at bitumen content, %		
			5.0	5.5	6.0
Deformation and strength indices at 20^0C in water-saturated state					
Compression strength	MPa	R_{20}	**3.32**	**4.00**	**2.94**
Steady-state stresses	MPa	σ_{y20}	3.32	3.4	3.35
Static modulus of elasticity	MPa	$E_{ст}$	194	210	196
Estimated modulus of elasticity	MPa	E_p	1462	1543	1473
Angle of internal friction	degree	φ_{20}	48.01	49,05	55,31
Adherence	MPa	C_{20}	0.22	0.22	0.16
Poisson ratio	-	ν	0.29	0.30	0.29

Summary

The proposed method of assessment of deformation and strength properties of asphalt concrete makes it possible:

– to speed up the assessment of quality of pavements construction and increase the reliability of the assessment, since comparison of indices for three types of mixes is supposed to be performed;
– to depart from pavement sampling;
– to make operative decisions on change of mix compound or technology of asphalt concrete laying and compaction.

References

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