VYNAPA - CZECH SOFTWARE UPGRADE FOR CALCULATION OF PAVEMENT DESIGN PARAMETERS USED BY HDM-4

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ABSTRACT

The HDM-4 model is capable of monitoring the condition of the pavement depending on multiple parameters and of designing and completing repair accordingly. This occurs based on the setting of degrading curves for damage and deformation in the pavement structure. Repair and maintenance work is strictly linked to the courses; of course this means a need for funding. If the degrading curves are not set correctly the need for repair may arise regardless of whether the pavement actually is in a condition requiring such repair.
One of the main factors affecting pavement degrading and, therefore, the behaviour of the HDM-4 model, is the so-called structural number (SN). There are many methods used globally to determine the SN value, based on the quantity and quality of the data available which might include: elasticity modules for the materials, pavement structure layer thicknesses, output from the back calculation programs, output from the FWD device or design characteristics of the road.
In the Czech Republic substantial inconsistencies have been detected in the current methodology for the coefficient determination; therefore, the expression of the structural number has been optimised both for new road constructions and for existing pavements. The calibration of pavement SN determination in the Czech Republic was carried out by means of the VYNAPA software which modelled pavement structures most frequently used in the territory.

Keywords: VYNAPA, CSHS, HDM-4, Structural Coefficients, Pavement Deflection

1. INTRODUCTION

Development of traffic infrastructure is an important precondition for the development of the Czech Republic's economy. From the perspective of costs, this is a highly demanding area with respect to ensuring operability alone, i.e. maintenance and common repair. Much higher still are the costs of reconstruction and modernisation work while new construction is naturally the most costly. With respect to the significance of traffic infrastructure for economic development, quick and good-quality accessibility of individual regions, improving quality of life but also with respect to the need for the Czech Republic's involvement in trans-European transport networks there are strong pressures to provide adequate funds in both the short- and medium-term.

The aforementioned need for road and highway network development results in a necessity to search for and use a model for efficient resource allocation in space and time while adhering to the principle of efficient use of funds. The issue of economic effectiveness assessment is paid due attention abroad; this is for instance one of the basic criteria used by the European Investment Bank to decide whether to provide a loan for a specific infrastructure program. The comparisons of the costs of road pavements during their lifecycles can use models.

All those models usually work on a similar principle which is mutual comparison of the costs of purchase and future costs of maintenance and repair for a few structural options while taking into account various factors with an impact on the costs. The ideal is to design the optimal structural solution for a road to maximise the use of the structure both from the perspective of the investor and of the road users and population of the areas concerned. The investor's main purpose is cost minimisation - investments, repair and maintenance costs and time demands of construction works. The priorities of road users are on the other side; these include primarily time and fuel savings, reduced vehicle wear and tear, lower accident numbers etc. The optimum is creating a methodology for comparing road options (from both the technical and economic perspectives) viable for a structural alternative selection not only by investors but also for the users themselves.

One of such well known assessment tools is the Highway Development and Management (HDM) model. In the Czech Republic, the conditions for use of HDM-4 model are stipulated under the code CSHS (Czech Road Assessment System) which constitutes the workspace of HDM-4 program calibrated to the conditions and parameters of the Czech road infrastructure.

HDM-4 is capable of monitoring the condition of the pavement in relation to multiple parameters and of proposing and implementing repair accordingly. This runs on the basis of the set up of pavement structure defect and deformation degradation curves. These are strictly followed by the deployment of repair and maintenance work which, of course, brings along a need for funding. Unless the degrading curves are set correctly a need for pavement repair might arise regardless of whether the pavement actually is in a condition requiring such repair.

One of the major factors affecting pavement degradation and, therefore, the calculation of the HDM-4 model is the so-called Structural Number (SN). There are many methods to determine the SN depending on the quantity and quality of data available which might include: elastic modules of the materials, pavement structure layer thicknesses, output from the back calculation programs, output from the FWD device or design characteristics of the road (traffic load level).

The calculation of SN for a new pavement design used most frequently is based on the AASHTO methodology and is as follows.

$$SN = 0.0394 \sum_{i=1}^{n} a_i \cdot h_i$$

where: a_i structural layer coefficient characterizing its behaviour
h_i thickness of i-th layer (mm)
n number of structural layers

The methods used to determine the *SN* value of an existing pavement is also based on the relation to the pavement surface deflection under the FWD. Therefore, the structural number *SN* of a pavement characterises its structure. A better term for the parameter would be "load-bearing capacity number" since this parameter expresses the load-bearing capacity of the pavement, or its individual layers in a certain manner.

Practice suggests a recognisable connection between *SN* and the final project assessment by HDM-4; therefore, an optimisation of the structural number expression has been undertaken for both new road construction and existing pavements. The determination of pavement *SN* in the Czech Republic was calibrated by means of the VYNAPA software which modelled pavement structures most frequently applied in the territory.

All methodologies used world-wide to determine *SN* build their hypotheses on the basic relationship stipulated by the AASHTO methodology. The methodology prevails globally; however, as mentioned in the AASHTO Guide the determination of structural coefficients for materials in the pavement structure although the relations are unique for the materials used in the AASHO Road Test modelling which is used as the supporting data for the subsequently issued American design methodology. AASHTO Guide recommends that each design organisation using such relations adjust the interrelations to specify the local materials actually used in the location (state) in road pavement structures. Unfortunately, the AASHTO Guide's list ends before the recommendation of a procedure suitable for use to determine structural coefficients in other locations. This results in constant issuance of new versions of structural coefficient determination and, analogously, structural numbers per se.

SN optimisation in the Czech Republic was carried out based on the known interconnections between the variables of new pavement *SN* (coefficients a_i), existing pavement *SN* (deflections from FWD), output from back calculation programs and SN_f (design structural number). The relations, determination methods, input parameters and factors affecting the values in question are depicted in fig. 1.

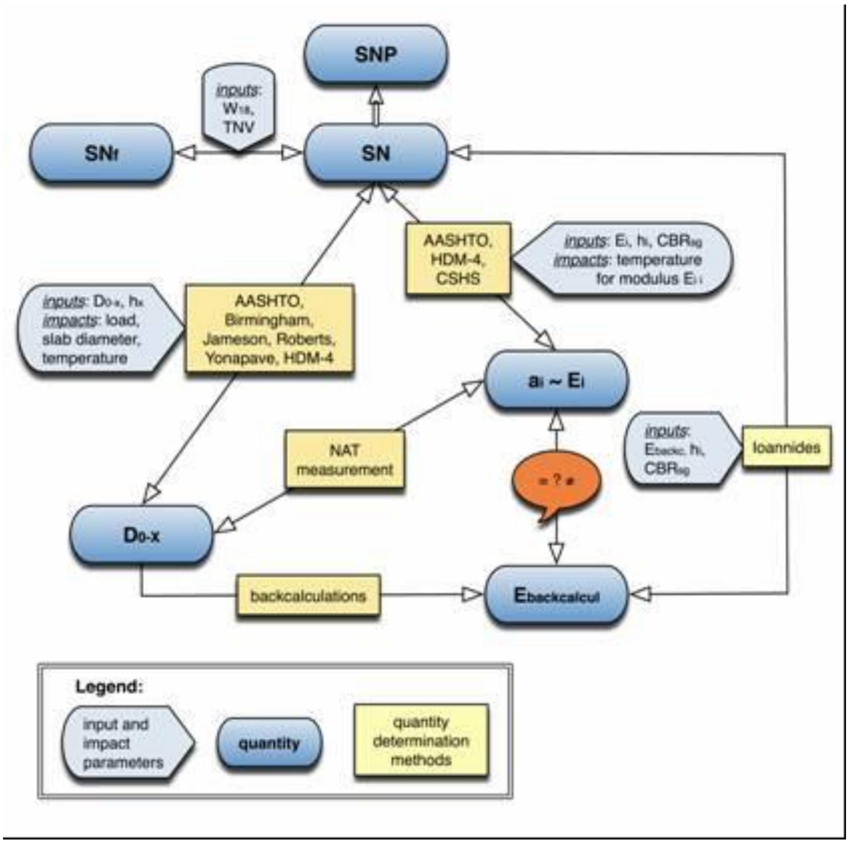

Figure 1: Optimization of setting of the structural number

To harmonise the structural number value, the Road Czech Technical University developed software VYNAPA ("**VÝ**počet **NÁ**vrhových **PA**rametrů" – Pavement Design Parameter Calculation). A spreadsheet editor simulated all available methods for structural number determination used world-wide for both new and existing pavements. When all dependencies had been compiled the software modelled the structures most frequently recommended (under Czech Pavement Design Manual TP 170) in the CZ for new pavement structures which eliminated methods with any extreme (unrealistic) result values (this eliminated the CSHS methodology). The resulting steps "left for" *SN* determination were sorted by comparing the structural number in a new pavement *SN* to the design structural number, SN_f. This number takes into account the use of the planned road or, in other words, the classification of the traffic load on the road.

2. METHODS OF DATA PROCESSING

2.1 Optimization of structural number (SN) determination on newly designed pavements in CZ

The determination of *SN* for new pavement structures is widely used within project assessment by means of HDM-4 methodology. In the case of investment plans for road construction, economic effectiveness of the construction must be evidenced by output from HDM-4. Correct setting of the input parameters might have a considerable impact on project acceptance or rejection. In this stage of determination, the value of *SN* is based on the project pavement structures including material specification for individual layers and thicknesses thereof.

The calculation of *SN* of a designed road pavement thus involves the thicknesses of individual pavement layers and the so-called structural coefficients a_i specified for each pavement layer in the categories as given in table tab. 1.

Table 1: Specification of structural coefficient according to applied layer

Type of structural layer	Structural coefficient
Asphalt concrete wearing and binder course	a_1
Bitumen stabilized base layers	
Cement stabilized base layers	a_2
Non-stabilized base layers	
Non-stabilized sub-base layers	a_3

A correct determination of coefficients for the conditions in the Czech Republic forms an inseparable part of the solution; the values of the coefficients depend on the representative characteristics of quality of the materials used in the relevant layer (elastic modulus, compression strength, CBR).
Optimisation of the determination of *SN* for new pavements in CZ was carried out using the VYNAPA software which modelled most frequently used pavement structures (using catalogue sheets TP 170).
A specimen of partial calculations by VYNAPA is given below in fig. 2.

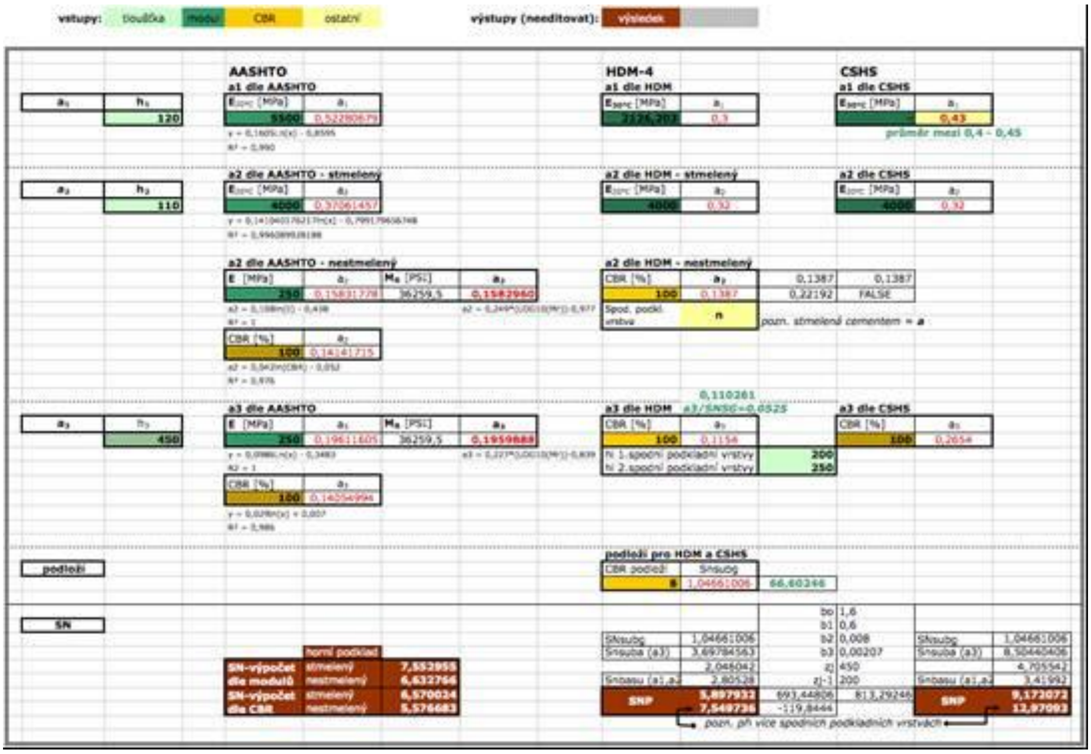

Figure 2: Partial calculations in VYNAPA

2.2 Optimization of structural number determination on existing pavement

All dependencies available for the determination of the structural number of an existing pavement from the deflectometer data were compiled by means of the VYNAPA program. The data obtained were standardised to the temperature necessary for each specific methodology and contact pressure at 700 kPa.
An example of the simulation of determination of individual relations within the framework of known methodologies was carried out e.g. using data from the diagnostics of motorway D5, section km 29,000 – 48,000 the partial calculation of which in VYNAPA are given in figs. 3 to 7.

Auxiliary conversion 700kPa to 800 kPa FWD

	deflection at 800 [mm]	load	deflection at 700 [mm]	temperature coefficients	y20	y30	real temperature on the road pavement
D0	**0,213**	800	0,186375	0,0027	0,199875	0,226875	**15**
D305	**0,169**	800	0,147875	0,0012	0,153875	0,165875	
D600	**0,133**	800	0,116375	0,0003	0,117875	0,120875	
D900	**0,102**	800	0,08925	0	0,08925	0,08925	
D1200	**0,077**	800	0,067375	0	0,067375	0,067375	
D1500	**0,056**	800	0,049	0	0,049	0,049	
D2100	**0,034**	800	0,02975	0	0,02975	0,02975	

Figure 3: Assignment of input parameters (temperature during diagnostics assessment, deflections including their optimization)

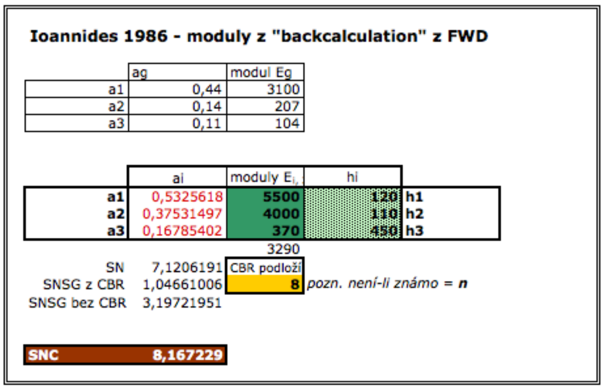

Figure 4: ***SNC*** **calculation by Ioannides methodology using modules of elasticity of odd layers by the program of back calculation**

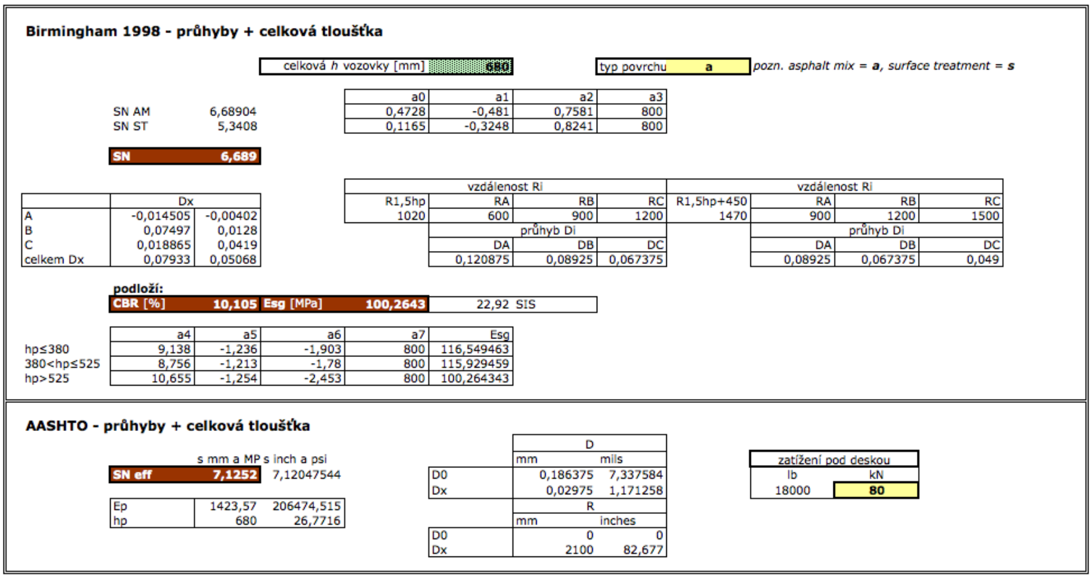

Figure 5: ***SN*** **and** ***SN$_{eff}$*** **calculation of a pavement together with** ***CBR*** **and** ***E$_{sg}$*** **calculation of subgrade by methodology according to TU Birmingham and AASHTO model; application of knowledge of the total pavement thickness, loading under the plate and temperature during the measurement**

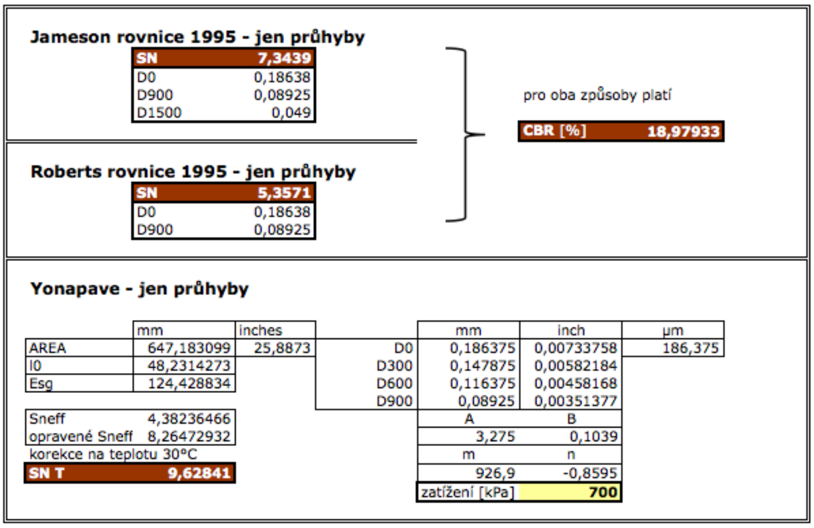

Figure 6: ***SN*** **and** ***CBR*** **calculation of subsoil by Jameson, Roberts and Yonapave methodologies using the knowledge of deflections resulting from FWD (hereafter loading under the plate at temperature during the measurement)**

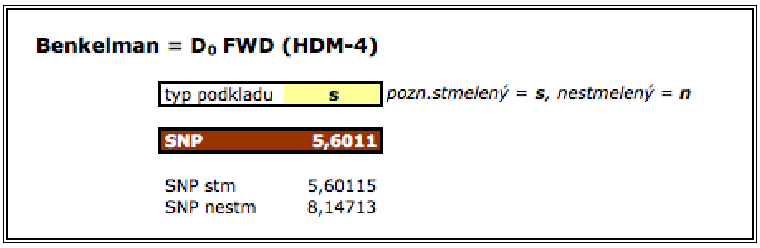

Figure 7: *SNP* calculation by HDM-4 methodology using only deflection data received by the central transducer at 30°C (identical with deflections received by the Benkelman Beam test equipment)

As can be seen in the tables above, different methodologies result in different *SN* final values. All of the methodologies researches, authors recommend applying their methodologies for local purposes in particular with respect to the materials used at the area of experiments and testing to determine the suitable *SN* calculation. This suggested the question: What methodology for determining the *SN* of existing pavements in the Czech Republic should be used? The effort towards answering the question results in a need to develop a new methodology to respect the materials used in pavement structures in the roads in the Czech Republic.

Nine basic expected regression models to be used as input for the subsequent statistical analysis have been compiled for this purpose. The recommended analysis should result in finding the statistical model with the highest correlation/probability value R^2 which would prove the best fit for the conditions of the Czech Republic.

3. RESULTS

3.1 Optimization of the structural number *SN* on Ely designed pavements in CZ

3.1.1 Final determination of structural coefficient a_1 for wearing and binder pavement courses

The process of determining a_1 for a new pavement structure involves, as main criteria, the elastic modulus according to the asphalt layer used; therefore, attention must be paid to realistic quantification of values of this parameter. With respect to the fact that the structural coefficient a_1 is determined for the entire pavement surfacing (the wearing as well as binder course) a conversion is recommended from a two-layer system to a single-layer system according to the simplified procedure using the weighted average with a view of individual elastic modules and thicknesses of both pavement cover layers.

$$E_K = \frac{E_O \cdot h_O + E_L \cdot h_L}{h_K} \quad ; \quad h_K = h_O + h_L$$

where: E_K optimized modulus of elasticity of wearing and binder course at 20°C [MPa]
E_O modulus of elasticity of pavement wearing course at 20°C [MPa]
E_L modulus of elasticity of pavement binder course at 20°C [MPa]
h_K thickness of wearing and binder course [mm]
h_O thickness of wearing course [mm]
h_L thickness of binder course [mm]

This method yields the input elastic modulus E_K (MPa) for the cover layers of thickness h_K (mm) for the determination of the structural coefficient a_1.

The VYNAPA software proved (when *SN* of various structures with SN_f as above have been compared) that the AASHTO methodology is the most relevant for the determination of a_1 (i.e. it reflects the elastic modulus value), although the upper limit of the modulus values used must be extended. For the purposes of making the coefficient realistic, the recommended upper limit 0.45 was shifted according to the regression equation (see figure 8):

$$a_1 = 0.1605 \cdot \ln(E_K) - 0.8595$$

where: a_1 structural coefficient of asphalt wearing and binder courses
E_K modules if elasticity at 20°C [MPa]

This measure, i.e. extending the limit value of 0.45 as determined by the American methodology, are more and more often used by authors of other contemporary methodologies based on AASHTO with respect to the past development in the quality improvement of materials applied nowadays. Another positive of using the methodology is the input value of the elastic modulus under 20°C which is a better reflection of the real conditions in the Czech Republic than the 30°C currently entered according to CSHS.

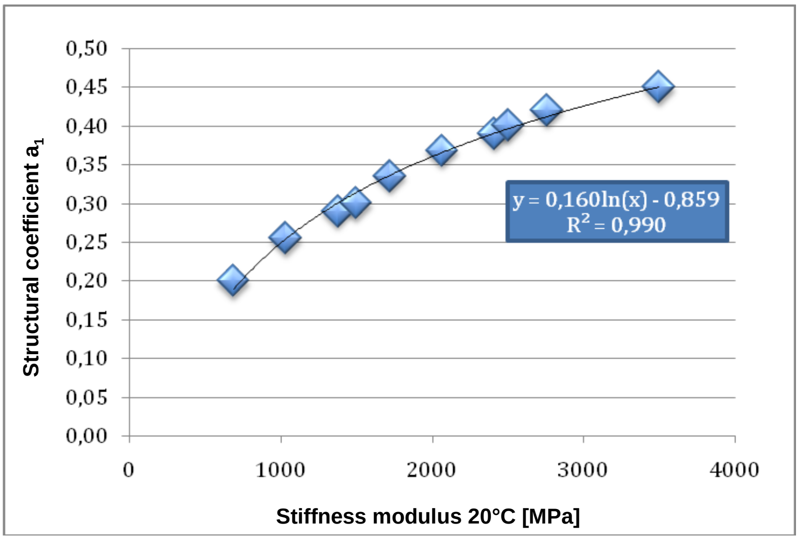

Figure 8: Correlation between the coefficient a_1 and modulus of elasticity of selected layer

3.1.2 Final determination of the structural coefficient a_2 for base layers

Again, bitumen-stabilised base layers used most frequently in the Czech Republic (including high stiffness modulus asphalt mixes) seem more suitable for the methodology according to AASHTO, with respect to significantly unrealistic simplification of HDM-4 or CSHS in the form of selecting just one value of the coefficient, 0.32, this time for all elastic modulus values. This method is detrimental to materials with more load-bearing capacity because their quality is not reflected in the value of a_2 and, analogously, the use of a base with less load-bearing capacity will have no effect on the resulting *SN* value. Again, the dependence of the a_2 coefficient on the elastic modulus was examined; with respect to the absence of a prescribed dependence equation according to the AASHTO methodology, a regress analysis was performed for the values from the nomogram and the basic logarithmic formula with a high reliability value was determined (see figure 9) as follows:

$$a_2 = 0.1410 \cdot \ln(E_{HP}) - 0.7992$$

where: a_2 structural coefficient of bitumen stabilized base pavement layer
E_{HP} modules of elasticity of base layer at 20°C [MPa]

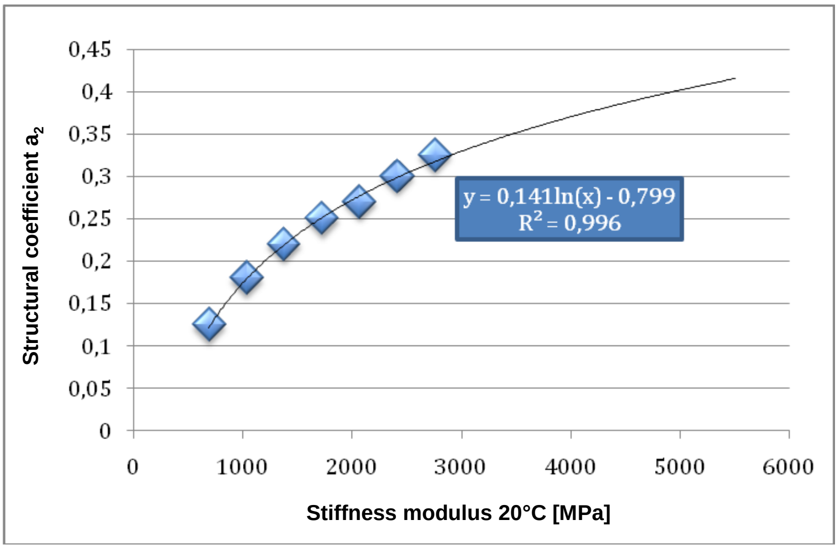

Figure 9: Correlation between the coefficient a_2 and modulus of elasticity of selected layer

Another group of materials used in those pavement layers are materials hydraulically bonded materials. The AASHTO methodology based on the materials' compression strength can be recommended for such layers. The compression strength of cement-bonded materials is tested according to AASHTO after 7 days' curing while according to the ČSN EN, the strength is tested on specimens after 28 days' humidity exposure in the Czech Republic. Therefore, a conversion of strengths had to be made for 7 days from the 28 days.

After optimising the compression strength, the mutual dependence of two values (a_i and *P*) was determined by means of the AASHTO nomogram as depicted in the following figure 10. The resulting equation for the determination of the structural coefficient thus has the following form according to the linear trend curve formula.

$$a_2 = 0.0229 \cdot P_{7days} + 0.0922$$

where: a_2 structural coefficient for hydraulically bonded base course
P_{7days} compression strength after 7 days curing [MPa]

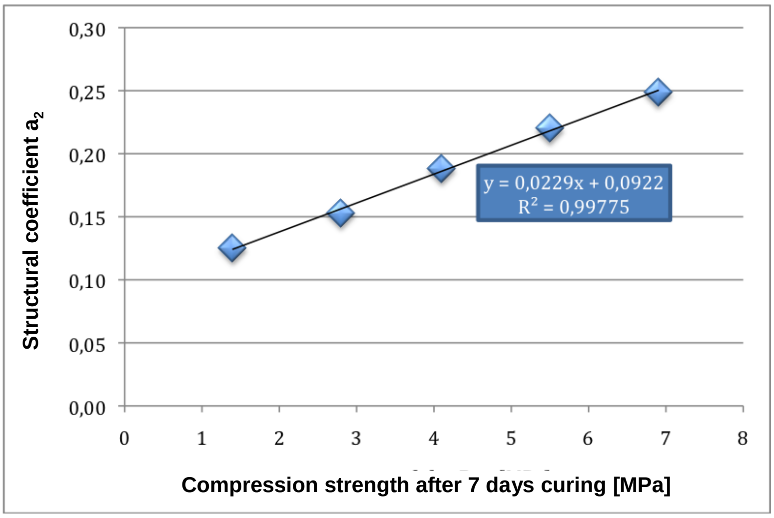

Figure 10: Correlation between the coefficient a_2 and compression strength

The case of non-stabilised material can be named as materials least used in the base layers. Such technologies are used primarily in pavement structures with low traffic load which, due to their character and utilisation, will not be entered in the HDM-4 assessment; however, the AASHTO methodology has proven the best option again as it allows determining the coefficient based on the materials' elastic modulus in contrast to the relation to *CBR* value that is the only one given in HDM-4. With respect to the character of the non-stabilized materials in such layers, it is more realistic in our conditions to start with the elastic modulus values which are also given in the Czech Republic's design methodology while the *CBR* value of such materials is not usually determined.
The resulting recommended equation for the calculation of the a_2 parameter for non-stabilised layers is as follows, with the additional commend that the absolute correctness thereof must be verified by further research which was not conducted with respect to the low level of use in our conditions.

$$a_2 = 0.249 \cdot (\log_{10} E_{triax}) - 0.977$$

where: E_{triax} modulus of elasticity of non-stabilized materials received by the triaxial test [MPa]

3.1.3 Final determination of structural coefficient a_3 for sub-base pavement layer

In contrast to the above, non-stabilised materials find most use in sub-base pavement layers. The methodologies available determine the structural coefficients for sub-base pavement layers based on their dependence on the *CBR* value of the non-stabilised material. This is the only structural coefficient to indicate the same value using both major methodologies (HDM-4 and AASHTO); therefore, even for the Czech Republic, the a_3 coefficient is recommended to obtain from the relation to *CBR* although the values of modules for the layers would be realistically more accessible. To determine the representative *CBR* values of materials used for the sub-base pavement layers in the Czech Republic, more experiments on various material types would be necessary; due to considerable demands this was not undertaken within the framework of the study. In the practice, *CBR* of the materials is not determined too often; therefore, research focusing solely on clarifying this issue would be most appropriate.
With respect to the fact that there are multiple sub-base layers (most frequently two), in order to determine the final *CBR* value from which the a_3 coefficient can subsequently be taken the multi-layer system must be converted to a single-layer system using the weighted average.

$$CBR_{SP} = \frac{\sum_{i=1}^{n} CBR_i \cdot h_i}{h_{SP}} \quad ; \quad h_{SP} = \sum_{i=1}^{n} h_i$$

where: CBR_{SP} optimized *CBR* value of sub-base pavement layers [%]
CBR_i *CBR* value of i-th sub-base pavement layer [%]
h_{SP} total thickness of all sub-base layers [mm]
h_i thickness of *i*-th sub-base layer [mm]

Again, the dependence of the coefficient on the *CBR* value was modelled according to the AASHTO nomogram available, and adjusted to our conditions. The resulting equation follows the trend curve given in the chart.

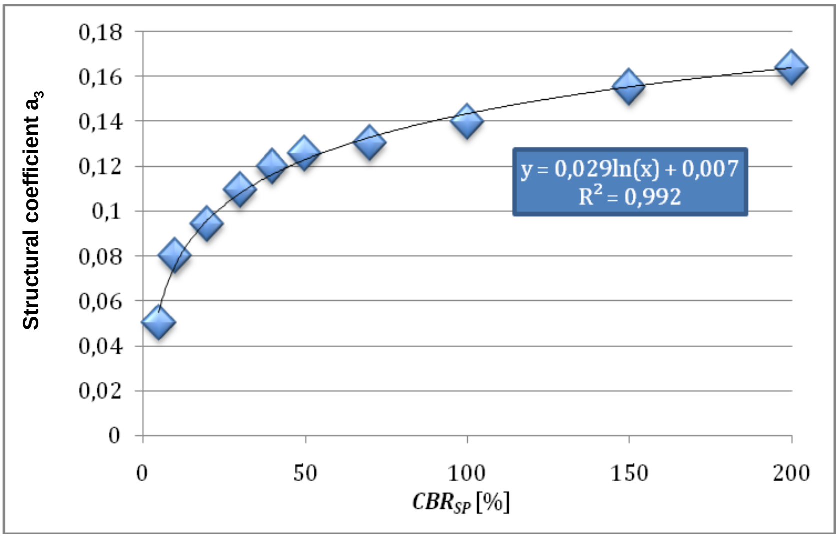

Figure 11: Correlation between the coefficient a_3 and the CBR value

According to the following equation, the value of the structural coefficient a_3 can be calculated with the CBR_{SP} value and the correlation diagram.

$$a_3 = 0.0295 \cdot \ln(CBR_{SP}) + 0.0077$$

When the three basic structural coefficients have been determined the structural number *SN*, i.e. the impact of the cover and base layers can be calculated according to the formula the fundamentals of which are common to all methodologies (AASHTO, CSHS, HDM-4), that is, according to the basic *SN* equation.

3.1.4 Final determination of subgrade influence

In the sense of the original AASHTO methodology, the calculation of the structural number does not include the impact of the pavement subgrade, therefore, as has been said above, the determination of this level of the structural number only represents the effect of the pavement structure (surfacing and base layers). However, the condition of the subgrade has a considerable impact on the load-bearing capacity of the pavement and, therefore, a formula to express the influence of the subgrade on the *SN* value was searched for. To introduce the effect of the subgrade in our conditions, the 1997 methodology (Parkman and Rolt) marked as SN_{SUBG} can be adopted.

$$SN_{SUBG} = (b_0 - b_1 \exp(-b_2 z_m)) \cdot (\exp(-b_3 z_m)) \left[3.51(\log_{10} CBR) - 0.85(\log_{10} CBR)^2 - 1.43\right]$$

where:	SN_{SUBG}	subgrade quotient
	CBR	CBR value of the subgrade [%]
	b_o, b_1, b_2, b_3	model coefficients
	m	number of sub-base pavement layers
	z	assessed depth from the surface of the sub-base layer [mm]

The calculation using the HDM-4 methodology and manual entry of the structural number value includes the original structural number according to the AASHTO methodology as the main parameter. It is also necessary to specify the *CBR* of the subgrade and the resulting *SNP*, a sort of adjusted structural number which takes into consideration the effect of the subgrade is calculated automatically by the program. *SNP* is thus an adjusted original structural number, *SN*, and can be expressed as follows.

$$SNP = SN + SN_{SUBR}$$

where:	SN_{SUBG}	subgrade quotient
	SN	"original" structural number

A flow diagram has been compiled for a better illustration of the issue (see figure 12) with the logical relations between individual layers and materials.

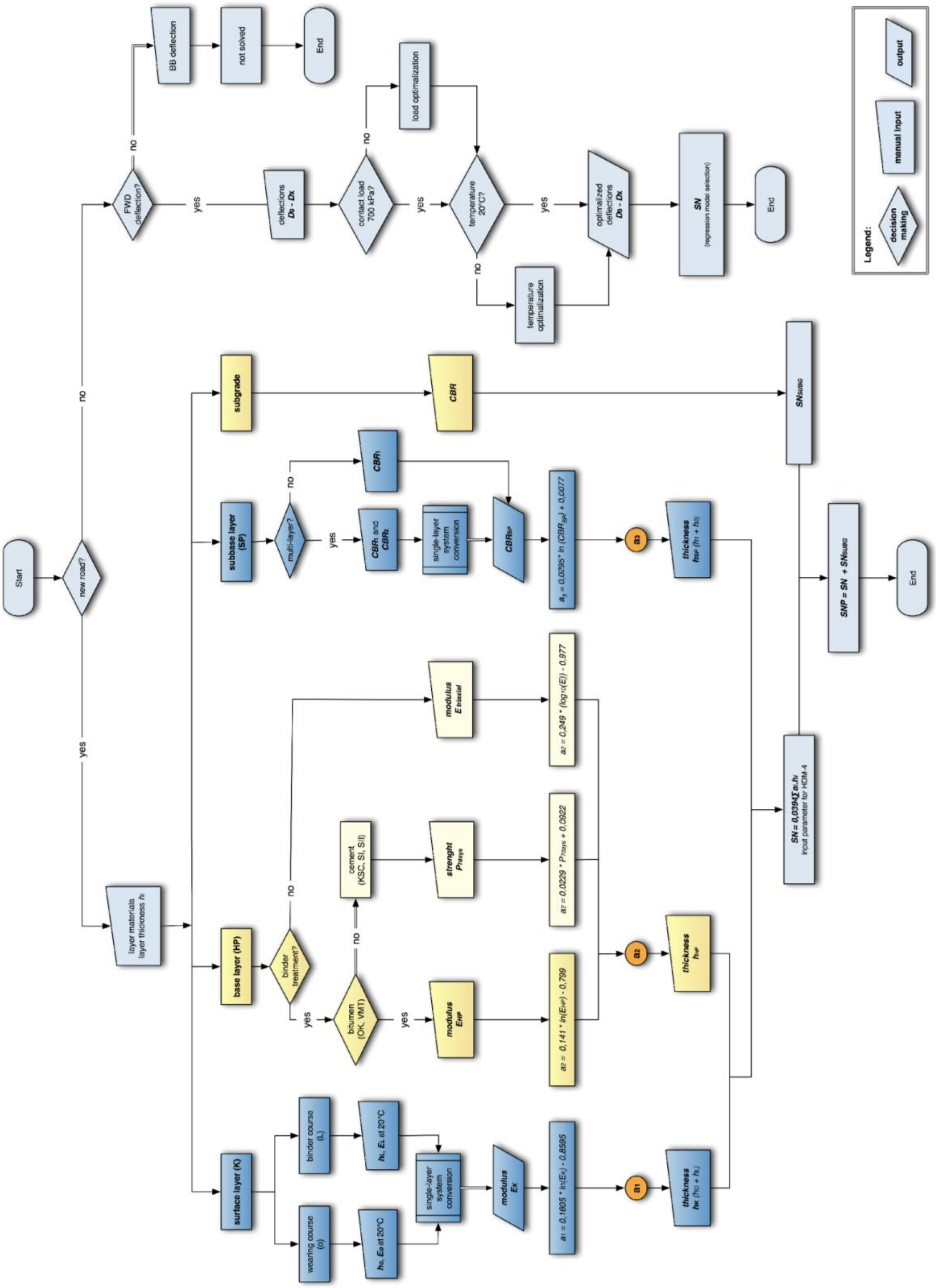

Figure 12: Flow-process diagram for structural number determination

3.2 Optimization of structural number determination on existing pavement

It can be noted that the determination of *SN* for an existing road according to the description in the HDM-4 methodology is insufficient. The main idea is based solely on the use of the central deflection under FWD which characterises the structure as a whole; however, it does not allow for determining the contributions of individual layers to the load-bearing capacity achieved. It is certainly appropriate to choose a methodology which will also respect the layer system of the pavement, that is, the calculation will also include other probes within the deflection curve which provide more information on the condition of the pavement in the equivalent depth equal to the distance from the centre of loading (using the relevant ordinate of deflection line). Due to that, nine different regression models were compiled for statistical analysis.

Having studied the principles already at work, it may be recommended to divide the pavement structures to two basic groups for regress analysis, namely those:

- with bitumen-stabilised sub-base layer
- with hydraulically-bonded sub-base layer

The recommendation is determining a separate regression model for each group due to non-homogeneous behaviour of the pavements with different sub-base layer types. Of course, the effect of temperature which is only reflected in bitumen-stabilised layers while the hydraulic binders are not significantly affected thereby must have a great impact on the different behaviours.

The analysis will be carried out on the prescribed nine regression models for the calculation of *SN* from the output from the deflectometer the results of which will be compared to the *SN* determined based on the modulus of elasticity of actual materials in the same pavement (at the same locations where the FWD diagnostics was performed). This would exclude the simplified consideration of *SN* correlation with the central deflection only (i.e. HDM-4). The *SN* determined on the materials will follow the methodology for structural coefficients a_i. Structural coefficients for individual layers will be attributed according to the actual elastic modules measured in the laboratory for the material samples taken and the structural number *SN* will subsequently be calculated with respect to the thicknesses of individual pavement layers.

The essence of the analysis can be generalised in the form of the following formula:

$$SN_{f(E_I)} = SN_{f(D_x)}$$

where: $SN_{f(Ei)}$ structural number *SN* specified as function related to material modulus of elasticity E_i

$SN_{f(Dx)}$ structural number *SN* specified as function of selected deflections D_X measured by FWD apparatus

The regression models for the determination of the *SN* of existing pavements have been found based on a literature search of the methodologies applied world-wide and on the assumption of ruling out the dependence on the thicknesses of individual pavement layers and other partial "side calculations" in the form of programs for back calculation of pavement parameters.

The prescribed regress models are mentioned in table 2 and include the dependence of the structural number on the deflections under FWD with probes in the distance of 500; 900; 1,200 and 1,500 mm from the centre of load which were found to have the best information value in relation to the condition of individual pavement structure layers (models 1 – 7) as well as the dependence on the *AREA* parameter, deflection under the sensor located 1,200 mm from the load centre and the distance of the fourth deflection sensor (model 8 - 9).

The remaining deflections, primarily the border deflections at distances exceeding 1,500 mm depend solely on the stiffness of the subgrade and, therefore, have not been taken into account in the analysis. The subgrade is sufficiently described by the sensors included in the analysis and the relation thereof to the central sensor follows the principle that small deflections at the border sensors are measured in a situation where the soil in the subgrade reaches high stiffness modules and, therefore, the *SN* determined in the models proposed for equal value of the deflection under the central sensor must be increased in cases where the deflection under the border sensor is reduced (the *SN* calculation responds to a "stiff" subgrade). In contrast to that, for the same deflection under the border sensor the *SN* must increase when the value of the deflection under the central sensor decreases (the *SN* calculation responds to the quality of the pavement structure).

Table 2: Regression models recommended for the analysis

Number of model	Equation for regression analysis
1	$SN = A + \frac{B}{D_0} + \frac{C}{D_{900}}$
2	$SN = A + B \bullet \log(D_0) + C \bullet \log(D_{900})$
3	$SN = A + \frac{B}{D_0 - D_{1500}} + \frac{C}{D_{900}}$
4	$SN = A + \frac{B}{D_0 - D_{1200}} + \frac{C}{D_{900}}$
5	$SN = A + B \bullet \log(D_0) + C \bullet \log(D_{1500})$
6	$SN = A + B \bullet [\log(D_0)]^2 + C \bullet [\log(D_{1500})]^2$
7	$SN = A + \frac{B}{D_0} + \frac{C}{D_{1500}}$
8	$SN = A + B \bullet [AREA]^{0,5} + C \bullet D_{1200}$
9	$SN = A + B \bullet [(AREA) - M \bullet D_{1200}]^{0,5}$

where: D_0 pavement surfacing deflection measured by a transducer placed in the middle of the plate at contact pressure of 700 kPa and temperature of 20°C [mm]

D_X pavement surfacing deflection measured by a transducer placed in the distance X from the centre of loading at contact pressure of 700 kPa and temperature of 20°C [mm]

X distance of the deflection transducer from the centre of the equipment [mm]; X = 900 mm, 1200 mm, 1500 mm

M distance of the fourth deflection transducer from the centre of the equipment [mm]

$AREA$ parameter in [mm] calculated form following equation:

$$AREA = 150 \cdot \left(\frac{D_0 + 2 \cdot D_{300} + 2 \cdot D_{600} + D_{900}}{D_0} \right)$$

A, B, C coefficients implicated from regression analysis

NOTE: Determination of the coefficients has to reflect the impact of subgrade and stiffness of pavement structural layers on SN and deflections in the pavement surface

The model must involve deflections from undamaged pavements (ideally just built ones) to prevent any possible defects (cracks, potholes, structural defects, etc.) from influencing the diagnostics by the FWD, i.e. the deflections measured, and from distorting the analysis results.

For the analysis to retain sufficient relevance, the equations must be derived from a sufficiently large data sample with a reasonable range of *SN* and subgrade stiffness values.

4. SUMMARY

The *SN* value is an important material characteristic respected in all advanced countries of the world; the correct calibration of the parameter could help the Czech Republic to find its place within these countries and to gain better advantage from program modelling by HDM-4 system in the sense that the outputs will reflect reality to a better degree and financial resources will be allocated to road construction in a more purposeful way. A correct determination of the *SN* value and, thereby, adequate setting of the entire HDM-4 system should result in an efficient, economical and purposeful use of funds for road preparation and construction.

The VYNAPA software is a helpful advanced tool for the determination of the optimal structural number value. In various modifications, it could be used for conditions other than in the Czech Republic as well.

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