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# PROBLEM RAISING: THE QUESTION OF DESIGN PROCEDURES DEPENDING ON THE COMPOSITION OF MIXTURES

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**Abstract.** *Different pavement structure design procedures have been carried out since 1960s in Hungary. The main principles of the most recent procedure were laid down in 1992 by Ervin Nemesdy, which was an empirical design guide. Unfortunately only corrections of the original procedure were implemented since then, no fundational improvement was made. In some European countries, in the USA, in Australia etc. Mechanistic-Empirical (M-E) Design Procedures were carried out and were put in practice. These procedures merge the mechanistic principles and the empirical experience of pavement behaviour. The Mechanistic-Empirical approach gives the opportunity to take into account some of the material properties, weather conditions, traffic datas and layer thickness. The technically suitable and cost-efficient pavement structure is calculated by an iteration process. Although with the Mechanistic-Empirical approach we can approximate the real behaviour of the pavement better, mechanistic tests of asphalt mixture can show different results as we expected. This paper lightens these differences, demonstrates what factor should be taken into account in a design procedure and it identifies research fields related to pavement design.*

**Key words:** *pavement design procedures, analytic design method, fatigue calculation, pavement checking, mechanistic test, lifetime calculation*

## 1. INTRODUCTION

The pavement structure means a multi-layer system, in which the task of the layers is to bear and spread the loads transferred from the wheel reduced to the layer below. According to the empirical design approach, the quality of materials deteriorates from top to bottom (wearing course, binder course, upper and lower base layer, earthwork, subsoil), and their layer thickness increases. However, the quality of the materials used must be determined by the requirements for the layer, so comparing the layers and ordering their quality is highly questionable. However, the quality of the materials and asphalts used

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largely depends on their composition, the grain distribution, the bitumen and void content. The Technical Regulation for Road Engineering provides a wide range of possibilities for choosing these, but it assumes the same quality material between the lower and upper limits, which also raises questions. Further uncertainty is inherent in production fluctuations, which will surely produce different results compared to the theoretically optimal composition of pre-designed asphalt. How can we take this uncertainty into consideration while designing pavement?

## 2. DESIGN PROCEDURES

To answer this question, you first need to briefly review the design procedures. The input parameters of the design procedure currently in Hungary [e-UT 06.03.13:2005], based on “type pavement structures”, were the traffic of each vehicle class and the design time frame. Taking into account the traffic development from these, the engineer got the design traffic volume (1), which showed how many ESALs (100 kN) would pass through the cross-section during the lifetime:

$$TF = z * 1{,}25 * 365 * t * r * s * f_N * (ÁNF_a * e_a + ÁNF_n * e_N + ÁNF_p * e_p + ÁNF_{ny} * e_{ny}) \quad (1)$$

The combined asphalt thicknesses of the type pavement structures, which were the result of design after the traffic load classification has been determined, smear the different properties of different layers and installed materials. [Nemesdy et al, 1992]. More studies showed, that the calculation of design traffic is outdated, and recommendations were made how to improve the traffic-increase parameter ($f_N$) and the vehicle-calculation parameter ($e_i$) [Soós et al, 2017]. Other authors suggested to take into account the horizontal wheel path in one lane [Adorjányi et al, 2009]. With the computational capacities and information flow available today, there is a well-founded need to be able to freely select the performance of asphalts – primarily its modulus and fatigue – as input parameters during design. Such mechanistic-empirical or analytical design methods have been developed and used in many countries around the world.

According to the most modern practice, pavement structure means mechanistic-empirical (M-E) procedures that determine and compare the stresses during the lifetime and the load bearing capacity of the structure. The M-E approach has replaced the empirical principle of a larger-traffic-thicker pavement, although the performance of the track structure is greatly influenced by layer thickness. The assumption of the mechanistic procedure is that, on the one hand, based on beam theory, asphalt breaks down due to tensile and compressive stresses due to bending, i.e. due to the tensile stress of the lowest fiber, and on the other hand, due to vertical compression caused by compressive stresses in the earthworks. However, they do not occur under the influence of a single high stress, but due to repeated small loads on the structure during its service life. These small loads eventually lead to fatigue failure. Based on Wöhler's laboratory experiments, he concluded that in addition to the periodically changing stress level, the number of repetitions associated with failure is higher the lower the value of level of stress, and he also described the logarithmic relationship between stress level and repetition number (Fig.1).

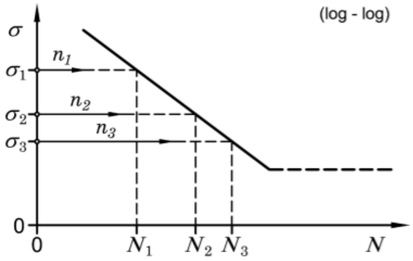

**Fig. 1.** Wöhler's line

This is used in material tests to determine the fatigue line. When designing, it is customary to use the *Palmgren-Miner* hypothesis, which speaks of accumulating damage. According to the *Miner principle*, for failure it is necessary to carry out a certain amount of work in the material. This work can be produced as an arbitrary combination of loads at different stress levels. (2)

$$\sum_i^k \frac{n_i}{N_i} \leq 1{,}0 \tag{2}$$

The flowchart of a M-E design procedure is shown in Figure 2. The input parameters of the analytical model are traffic, layer thickness and material properties (such as rigidity, Poisson factor). The model calculates the stresses arising from the unit load and, using the fatigue relationships, determines a permissible axle number, which is used to calculate the conformity of the structure. In case of noncompliance or oversizing, the process is restarted by changing the input parameters until the engineer does not get a suitable, cost-efficient pavement structure.

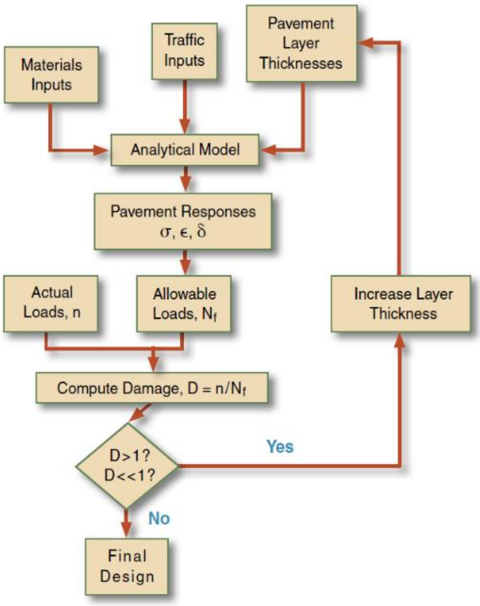

**Fig. 2.** Flowchart of M-E design [Asphalt Pavement Alliance, 2000]

## 3. STRESSES OF ASPHALT AND WAYS OF FAILURE

Next, let us review the stresses raising in pavement and the ways of failure of asphalt. According to the traditional approach, asphalt is a viscoelastic material, its properties largely depend on temperature. This is challenging in modeling and affects how it fails. In the high temperature range, more rigid asphalts (bitumens) with higher viscosity perform better, while at low temperatures, on the contrary, those are the more flexible asphalts with lower viscosity. A problem in modeling is that asphalt properties change with temperature, so complex rheological models are needed during design. It also causes problems in the development of testing methods. In winter, in the extreme cold, the modulus of asphalt can reach the modulus of concrete (their linear coefficient of thermal expansion is still not the same!), while in summer its viscosity can decrease so much that it suffers from great deformation even under small loads (e.g. car wheels). Thus, it is easy to see that if the properties of asphalt depend on temperature to such an extent, the failure modes are also "bound" to temperature ranges. [Koch et al, 2021] These ranges are illustrated in Figure 3.

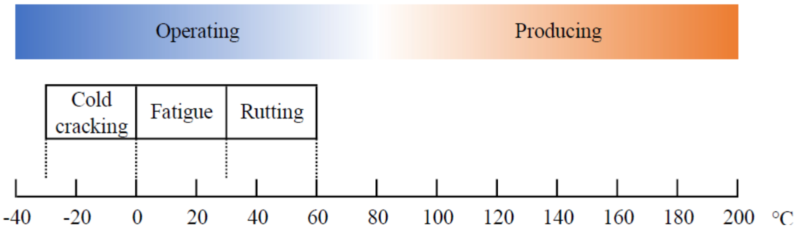

**Fig. 3** Temperature ranges in lifetime of asphalt (source: self-made)

Rolled asphalt is produced at 160-180 °C, only MA is produced hotter (200-220 °C). Using various energy-saving processes, production at temperatures of up to 100-120 °C is possible. However, the operating temperature is lower, but it is a very wide range, in Hungary it can be between -30 - + 60 °C, but in other places more extreme temperatures can occur. Cold cracks occur below 0°C due to sudden cooling or severe cold, and rutting occurs in hot weather, usually between 30-60°C. Fatigue failure can be linked to an average temperature range, since fatigue is caused by all passed axes.

It is an interesting question what damage an axle causes in pavement at different temperatures. Temperature data is available with long time series. A new design procedure could also take into account the weather conditions under which the pavement will operate, for example with average temperatures with confidence levels over the seasons [Gribovszki, Kalicz, Herceg, Primusz et al, 2020]. The moduli of layers depend on the temperature and the depth of the layer. The range of temperature and so the range of moduli of layers can be large which should be taken into consideration. [Witsuba, Micheal et al. 2018] It is also necessary to examine the annual distribution of traffic and treat it as an input parameter. An excellent example of this is the M7 motorway, where the greatest load is placed on the pavement in summer, under the hottest, i.e. the most unfavorable weather conditions.

It is also worth considering how the load is distributed along the vertical profile view of the pavement (Fig. 4). Assuming the asphalt layers to work together and be continuously and flexibly supported, the distribution of bending is linear within the track structure. However, the highest shear stresses do not follow such an orderly distribution. The maximum shear and compressive stresses are located at or below the boundary of the wearing course and binder course, while at the bottom of the track structure these stresses are at minimal level.

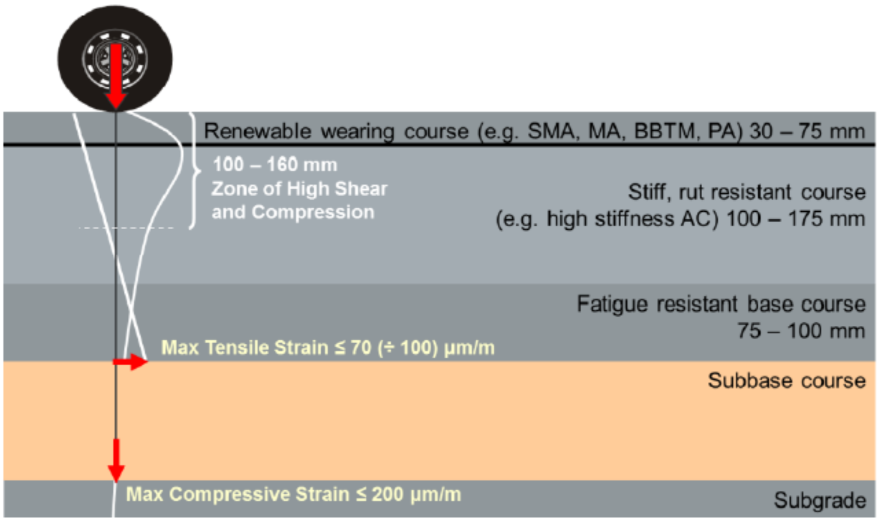

**Fig. 4.** Stresses in vertical profile view [Newcomb, Kent et al, 2006]

## 4. DESIGN SOFTWARE

Next, consider some existing and commercially available analytical design software. They have been developed by various research groups for commercial purposes, possibly for national standards. They are built on similar principles, their purpose is to determine the standard stresses, some of them count on lifetime, reliability, etc. They differ in what input data should be provided, in what form.

The European Union's Amadeus project [5] compared several design software and prepared a uniform scaling process involving 15 countries, including Hungary. The project consisted of three phases. In the first phase, the calculated results of the models were compared (11 pieces of software, e.g. Shell Bisar, Weslea). The conclusion of the first phase is that the parameters calculated by the software are approximately the same. In the second phase, the calculated values of the software were compared with those measured in the test phases, based on which the individual software was qualified. As a third phase, the performance of the track structure was determined with software and compared with 23 years of data series of test phases. In this case, the parameters studied were fatigue cracks, displacement, IRI and PSI. In the third phase, the results showed significant differences. In summary, the Amadeus project pointed out that software based on multi-layered elastic theory is easy to use, making 2D finite element software more complex and has little advantage over multi-layered flexible models.

**Table 1** Comparison of softwares

| Software | Shell Bisar | Weslea | PerRoad | Elza |
|---|---|---|---|---|
| Number of layers | ≤10 | ≤5 | ≤5 | ≤10 |
| Temperature input | No | No | Yes | No |
| Maximum stresses | Yes | Yes | Yes | Yes |
| Permissible stresses | Yes | Yes | No | Yes |
| Lifetime calculation | No | Yes | Yes | No |
| Suitability | High | High | Specifically for Perpetual Pavement | Medium |
| Usability | Medium | Medium | Difficult | Easy |

Shell Bisar software is the most widely used software by engineers. It assumes a linear relationship between stress and deformation, the layers are homogeneous, isotropic and infinite in horizontal direction. The number, thickness, Young's modulus and Poisson factor of layers, as well as the number, type and location of loads shall be provided as inputs. Critical stress sites layers should be set at the boundary of the layers (e.g. 3/4), specifying the depth. As a result, it calculates the stresses from the load at critical locations, e.g. deflection at the top of the track structure, horizontal elongation at the bottom of the asphalt, compression at the top of the earthworks. With batch mode, you can quickly calculate a pavement "package".

Weslea software is similar to Shell Bisar, its input parameters are almost identical. You can choose between metric and imperial units. An important difference is that only 5 layers can be designed with it, and that it can only automatically calculate the service life if the asphalt is combined into one layer. Different load types can also be specified here. Locations can be specified as desired.

The software, called PerRoad, was developed specifically for designing perpetual pavement. It does not calculate permissible and maximum stresses, instead it analyses the failure on a probabilistic basis, using the Monte-Carlo method. It allows you to take into account the weather and even automatically compares the moduli of each layer to the specified temperature data. Its disadvantage is that it only works with imperial units, which requires additional conversion, and therefore it is practically impossible to specify the binder, since the binder characteristics defined in the Hungarian regulations (penetration, softening point) and the bitumen classes characterized by the Anglo-Saxon maximum-minimum temperature cannot be matched.

Elsa is a Hungarian-developed, easy-to-use sizing software. It shows the user the track structure in spectacular, graphical form, where the number and thickness of layers can be set. The moduli are set by the program itself, automatically calculating the permissible stresses based on the design traffic. The places of use cannot be changed, there are only two, horizontal elongation at the bottom of the combined asphalt layer and vertical compression at the top of the earthworks, the comparison is carried out automatically, no matter the service life.

## 5. A CASE STUDY

In the following we present a case study to illustrate the differences between empirical and analytical pavement design and the effect of ignoring some of the material properties. With the help of the WESLEA software presented in the previous chapter, we execute a pavement checking and a backcalculation based on asphalt mechanical tests. We cannot talk about pavement design because the modelled pavement structures are the result of a design procedure based on empirical “type pavement structures” approach. The analytical workflow was based on the research report of Tóth and Primusz: *New Hungarian Mechanistic-Empirical Design Procedure for Asphalt Pavements*. [Primusz, Tóth et al, 2016]. In the following chapters we refer to this research report as Design Procedure. For the backcalculation, in addition to a traditional pavement structure, we also examine an innovative one, so-called Perpetual Pavement. We want to demonstrate how material properties influence the fatigue life and why these properties should be taken into account during modeling.

### 1.1. Pavements

**Table 2** Pavements

| Traditional Pavement | Perpetual Pavement |
|---|---|
| 4 cm SMA 11 (mF) wearing course | 4 cm SMA 11 (mF) wearing course |
| Pmb 25/55-65 | Pmb 45/80-65 |
| 7 cm AC 22 (mNM) binder course | 12 cm AC 22 (mNM) binder course |
| Pmb 25/55-65 | Pmb 25/55-65 |
| 12 cm AC 32 (mF) base course | 8 cm AC 22 (mF) base course |
| Pmb 25/55-65 | Pmb 45/80-65 |
| 20 cm CKt-4 base layer | 20 cm FZKA 0/32 ($E_2 \geq 144$ MPa) baselayer (crushed stone base layer with continous gradation) |

### 1.2. Calculation steps

The principle of checking is that the permissible tensile strain and compression strain calculated from the design traffic should be less than the maximum stresses determined by design software (WESLEA).

The structure is suitable if the permissible tensile strain of the lowest fibre of asphalt is greater than the maximum tensile strain (με):

$$\varepsilon_{tper}^{asphalt} \geq \varepsilon_{tmax}^{asphalt} \tag{3}$$

and the permissible compression strain of the earthwork is greater than the maximum (με):

$$\varepsilon_{vper}^{earthwork} \geq \varepsilon_{vmax}^{earthwork} \tag{4}$$

On the basis of the Design Procedure, permissible tensile strain and compression strain shall be determined.

$$\varepsilon_{tper}^{asphalt} = \left[\frac{F}{SF}\right]^{0,2} * \frac{10^4 * (0,856 * V_b + 1,08)}{E_a^{0,36} * TF^{0,2}} \tag{5}$$

$$\varepsilon_{vper}^{earthwork} = \frac{6000}{TF^{0,23}}. \tag{6}$$

Where

- F, safety factor, F = 1,00, or 1,50, depends on type of bitumen. In this case: F = 1,50.
- SF, value of Shift-factor, in case of FZKA SF = 3,00; in case of CKt SF = 2,50; in case of bitumenous base layer (AC) SF = 5,00.
- TF, a design traffic, TF = 13 981 781 ESAL (given data)
- $E_a$, modulus of asphalt layer
- $V_b$, volume of bitumen in asphalt, Table 3.

**Table 3** Characteristics of asphalt layers

| Asphalt layer | Equivalent asphalt modulus [MPa], 20 °C | Volume of bitumen in asphalt [%] | Poisson-factor [-] |
|---|---|---|---|
| Wearing | 4 000 | 12,8 | 0,35 |
| Binder | 10 000* | 11,4 | 0,35 |
| Base | 4 500 | 11,0 | 0,35 |

The asphalt modulus values given in Table 3. are recommended by the Design Procedure, except for binder course, which have a characteristic value of the big modulus of the binder course. In the Design Procedure, these values have been determined in such a way that fatigue damage accumulated at one temperature over a year is equal to the fatigue damage that occurs in asphalts with constantly changing modulus due to temperature changes.

Since the calculation is very complicated in the case of multi-layer systems, three-layer models were built. To do this, it is necessary to merge asphalts into one layer. The Design Procedure has a process for that.

When combining two layers, the common modulus of the two layers is equal to that of the bottom layer, their common thickness is determined as follow:

$$h_a = \left[\frac{A^4+4A^3N+6A^2N+4AN+N^2}{(A+1)^3(A+N)}\right]^{1/3} * (h_{a1} + h_{a2}) \tag{6}$$

where,

$$A = \frac{h_{a2}}{h_{a1}} \text{ and } N = \frac{E_{a1}}{E_{a2}} \quad (7)\ (8)$$

where,

- $h_{ai}$, thickness of layer i
- $E_{ai}$, modulus of layer i.

The line can continue for any length of time, so after combining the wearing and binder course, the common layer must be merged with the base layer. Thus, the common modulus of the asphalt layer is equal to the modulus of the lower layer.

Characteristics of other layers are shown in Table 4:

**Table 4** Characteristics of other layers

| Layers | Layer modulus [MPa] | Poisson-factor [-] |
|---|---|---|
| CKt-4 | 2000 | 0,2 |
| FZKA | 280 | 0,4 |
| Earthwork | 80 | 0,4 |

The layer moduli and Poisson factors are the same as recommended in the Design Procedure. The modulus of the earthworks is $E_2$ = 80 MPa prescribed at the time of covering. FZKA is also the value recommended in the Design Procedure (it can also be derived by calculation).

Moduli of layers were calculated as the Design Procedure recommended, but they are based on Hungarian Technical Specifications [e-UT 06.03.21:2018, e-UT 05.02.11:2018].

### 1.3. Checking process

Input parameters are shown in Table 5. and Table 6.

**Table 5** Inputs of traditional pavement

| Layers | Thickness [mm] | Design modulus [MPa] | Poisson factor [-] | V<sub>b</sub> | SF | F | Equivalent moduli and thickness |
|---|---|---|---|---|---|---|---|
| Wearing | 40 | 4000 | 0,35 | 12,8 | 5,00 | 1,5 | $E_a$ = 4500 MPa<br>$H_a$ = 241 mm |
| Binder | 70 | 10000 | 0,35 | 11,4 | | | |
| Base | 120 | 4500 | 0,35 | 11,0 | | | |
| CKt | 200 | 2000 | 0,2 | | 2,50 | | |
| Subbase | infinite | 80 | 0,4 | | | | |

**Table 6** Inputs of perpetual pavement

| Layers | Thickness [mm] | Design modulus [MPa] | Poisson factor [-] | $V_b$ | SF | F | Equivalent moduli and thickness |
|---|---|---|---|---|---|---|---|
| Wearing | 40 | 4000 | 0,35 | 12,8 | 5,00 | 1,5 | $E_a$ = 4500 MPa<br>$H_a$ = 254 mm |
| Binder | 120 | 10000 | 0,35 | 11,4 | | | |
| Base | 80 | 4500 | 0,35 | 11,0 | | | |
| FZKA | 200 | 280 | 0,4 | | 2,5 | | |
| Subbase | infinite | 80 | 0,4 | | | | |

Limit values determined from design traffic:

$$\varepsilon_{tper}^{asphalt} = \left[\frac{F}{SF}\right]^{0,2} * \frac{10^4 * (0,856 * V_b + 1,08)}{E_a^{0,36} * TF^{0,2}} = 149\ \mu\varepsilon$$

$$\varepsilon_{vper}^{earthwork} = \frac{6000}{TF^{0,23}}. = 136\ \mu\varepsilon$$

From the formula for permissible tensile strain of asphalt, the permissible number of axles passes, which means the service life, can be derived.

$$N_{per} = \left[\frac{F}{SF}\right]^{0,2} * \frac{10^4 * (0,856 * V_b + 1,08)}{E_a^{0,36} * \varepsilon_{tmax}^{asphalt}} \tag{9}$$

The standard stresses were calculated using the target software called WESLEA, assuming a complete shift between the layers, so there is no bonding.

The final results of the calculation are shown in Table 7.

**Table 7** Final results of checking

| Modell | $\varepsilon_{tper}^{asphalt}$ [με] | $\varepsilon_{vper}^{earthwork}$ [με] | $\varepsilon_{tmax}^{asphalt}$ [με] | $\varepsilon_{vmax}^{eartwork}$ [με] | $N_{per}$ [ESAL] |
|---|---|---|---|---|---|
| Traditional | 149 | 136 | 131 | 105 | 26 308 820 |
| Perpetual | | | 136 | 103 | 21 815 406 |

Since the permissible stresses depend only on the design traffic (13 981 781 ESAL), they are the same for both pavements. The maximum strains are almost identical, but the differences are minimal. In both cases, the maximum strains are lower than permissible ones, the structures are suitable. If we look at the fatigue life we find that the traditional one has almost twice the required and the perpetual one has 50% more than required which means they are oversized.

### 1.4. Backcalculation of fatigue life based on asphalt mechanistic tests

The fatigue tests shall be carried out using the four-point bending method (4PB-PR). The essence of this test is to apply a sinusoidal force or, in this case, displacement to the trial object at two points at a temperature of 20 °C at a frequency of 30 Hz. The advantage of four-point testing over two- and three-point tests is that a constant stress level is established between the two load points, therefore its reliability is higher. The test is displacement-driven with three different displacements. The trial object is 50 × 500 × 400 mm. 18 trial object is required to run the test. The test lasts until the initial modulus is halved. A regression line/curve shall be fitted to the repetitions for a given displacement on a logarithmic scale.

The regression curve:

$$y = a * x^b \tag{10}$$

where,

a – ordinate of curve
b – direction-factor of curve.

Where this straight line (in Cartesian coordinate system a curve) reaches $10^6$ repetitions, the specific deformation corresponding to that value becomes the fatigue resistance value of the asphalt mixture, in με.

By substituting into the equations of the fatigue curves the maximum stresses previously calculated with analytical design process, the number of repetitions, i.e. the service life, can be backcalculated.

The equations for fatigue curves after the four-point bending test have been carried out:

$y = 1001{,}7 * x^{-0{,}133}$ , for traditional base course AC32

$y = 652{,}08 * x^{-0{,}095}$, for fatigue-resistant base course (perpetual pavement)

It can be seen from the parameters of the curves that the fatigue resistance of AC 32 is higher at low repetitions (parameter a), but the path of the curve is much steeper because its direction factor (parameter b) is lower. In contrast, the curve of perpetual asphalt flattens.

In equations, y represents the specific elongation in με, while x represents the number of repetitions. After sorting, the following formula is used to calculate the lifetime:

$$x = N = \sqrt[b]{\frac{y}{a}} \tag{11}$$

Knowing the parameters, a and b, replace y with the values of the previously calculated standard stresses. Then substitution of x = N gives the allowed number of repetitions in Table 8.

**Table 8** Number of repetitions allowed

| Modell | Parameters | | $\varepsilon_{tmax}$ | Repetition |
|---|---|---|---|---|
| | a | b | [με] | N |
| Traditional | 1001,7 | -0,1333 | 131 | 4 242 821 |
| Perpetual | 625,08 | -0,095 | 136 | 9 388 513 |

The results show that the pavement with higher stresses has 2.5 times longer fatigue life than the pavement due to better material properties. This is a significant difference, especially considering that the result of M-E design was the opposite.

### 1.5. Comments to think about

This calculation was only one example and should be treated with reservations along the following points:

- Merging several asphalt layers into one layer is a major simplification. The errors resulting from this simplification are carried forward by the calculation
- The procedure was basically developed for the construction of a traditional pavements
- Although the implemented design method can partially take into account the properties of polymer-modified bitumen, it cannot take into account the properties of high-performance new bitumen [e.g. rubber – bitumen, Almássy, Gáspár et. al, 2020]
- The input parameters of asphalts are predetermined values, although there are publications and design procedures which are capable to treat inputs with mean value and distribution, resulting in a probabilistic method and design output values with confidence level [Ahmed Abed, Nick Thom, Luis A. C. Neves et al, 2019]
- The moduli of asphalts have a great influence on the calculation
- The fatigue characteristics is not specified as an input parameter, resulting in a difference between the lifetime calculated from the mechanical test and the final result of the modelling

## 6. CONCLUSION

Since the 2000s M-E design methods have appeared in many parts of the world. The common essence of these is that besides traffic and lifetime, other parameters are also treated as input parameters during the iteration process, such as mechanical properties of asphalt, weather data, layer thicknesses.

A variety of software is easily commercially available. They operate on the basis of stress relationships of multilayer flexible mechanical models on a similar principle. Their input parameters and the results of their calculations are almost identical, with differences in accessibility, manageability and details of model.

It is worth expanding the range of input parameters, fatigue properties and weather data, as simplifications and merging always result in errors.

A Hungarian procedure has also been carried out in recent years, which certifies the suitability of the type pavement structures and may even result in the designing of more economical structures.

However, it can be seen what reservations should be made about this procedure as well. Only by taking into account the material properties in as much detail as possible can the behavior of pavement structures be modelled in a realistic way. Not only the moduli of asphalts should be an input parameter, but also their fatigue resistance, since the service life is not characterized by the initial value of the fatigue curve, i.e. the initial stiffness, but by its course.

If asphalt mechanical properties (fatigue, modulus) become target values in the mixture design, the effect of the composition on performance should be examined and predicted in as much detail as possible.

## 7. FUTURE RESEARCH FIELDS

The development of a new, mechanistic-empirical design procedure that treats asphalt properties, weather data, traffic distribution and asphalt stresses as input parameters is a huge task: it requires large capital, human resources and many years. We should mention the recent work of Csaba Tóth and Péter Primus, who have already developed an analytical design method in Hungary presented in this study. The issue of design is extremely diverse. In this complex, multi-component system, the following questions need to be addressed [Füleki et al, 2020]:

How does the performance of asphalts change if the components vary between the extremes of the limits according to the Technical Specifications for Roads?

How can uncertainty due to the impact of production fluctuations on composition be taken into account during design process?

What impact does this have on the lifetime of the pavement structure?

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# RAZMATRANJE PROBLEMA: PITANJE PROCEDURA PROJEKTOVANJA U ZAVISNOSTI OD SASTAVA MEŠAVINA

*Različite procedure projektovanja kolovozne konstrukcije su sprovođene od 1960-ih u Mađarskoj. Glavne principe najnovije procedure postavio je 1992. Ervin Nemesdi, a to su bili empirijska uputstva za projektovanje. Nažalost, od tada su sprovedene samo ispravke prvobitne procedure, nije bilo suštinskih poboljšanja. U nekim evropskim zemljama, u SAD, u Australiji itd. Mehanističko-empirijski (M-E) projektni postupci su obavljeni i sprovedeni u praksi. Ovi postupci spajaju mehaničke principe i empirijsko iskustvo ponašanja kolovoza. Mehanističko-empirijski pristup daje mogućnost da se uzmu u obzir neka svojstva materijala, vremenski uslovi, podaci o saobraćaju i debljina sloja. Tehnički pogodna i isplativa kolovozna konstrukcija se izračunava iteracijskim procesom. Iako mehaničko-empirijskim pristupom možemo bolje aproksimirati stvarno ponašanje kolovoza, mehanička ispitivanja asfaltne mešavine mogu pokazati drugačije rezultate kao što smo očekivali. Ovaj rad umanjuje ove razlike, pokazuje koji faktor treba uzeti u obzir u postupku projektovanja i identifikuje oblasti istraživanja u vezi sa projektovanjem kolovoza.*

Ključne reči: *procedure projektovanja kolovoza, analitička metoda projektovanja, proračun zamora, provera kolovoza, mehaničko ispitivanje, proračun životnog veka.*