

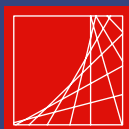
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The soil-structure seismic interaction phenomenon necessity and approach

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Summary

Seismic soil-structure interaction analyses have achieved considerable improvement, over the world, concerning the definition of the seismic environment, the evaluation of soil properties and the estimation of the structural response.

The design of NPP on soft-to-medium stiff soils during the last decades has contributed to this improvement and a tendency to apply the soil-structure seismic interaction analyses for some special conventional buildings has also to be noted.

The paper presents the state-of-the-art concerning the soil-structure seismic interaction analyses, the uncertainties involved in soil-structure seismic interaction analyses and some aspect referring to the accuracy in performing such analyses.

The article will also contain theoretical problems of the soil-structure interaction, comments on ASCE 4-86 [1] norm presenting both the modeling and analysis ways of the soil-structure seismic interaction phenomenon.

KEYWORDS : Seismic soil-structure interaction, dynamic interaction, seismic excitation, structural response, foundations soil, frequency filter, deforming bearing, dynamic behavior of the massive soil, uncertainties.



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1. INTRODUCTION

In the seismic analysis of structures, the dynamic soil-structure interaction can sensibly influence the structural response. The rigor of soil-structure interaction analysis at seismic actions is related to the correctness of modeling the system made of structure and soil massive, to the accuracy of the values of the parameters defining the seismic excitation and to the physical-mechanical properties of the soil.

The theoretical and experimental investigations made lately approach a series of aspects where the soil-construction seismic interaction can be significant and for which the current approaches are not satisfactory: buried and partially buried structures (special constructions, tunnels, pipes etc), flexible foundations and columns foundations, seismic pressures on structure walls, etc.

The article will contain theoretical problems of the soil-structure interaction, comments on ASCE 4-86[1] norm presenting both the modeling and analysis ways of the soil-structure seismic interaction phenomenon and the uncertainties that governs the soil-structure seismic interaction phenomenon.

2. THE SOIL-STRUCTURE SEISMIC INTERACTION PHENOMENON NECESSITY AND APPROACH

In the seismic analysis of structures, the soil-structure dynamic interaction can sensibly influence the structural response. The soil massive acts, when interacting with the construction, indirectly like a frequency filter and directly like a deforming bearing on an active area situated in its vicinity. The deforming bearing and the dynamic filter roles are interrelated and have a major importance for the seismic response of the structure. The dynamic properties of the subsystems that are under the influence of the structure-massive soil interrelation lead to insignificant effects when the foundation soils are rigid, but become significant for deforming, weak foundation soils.

The soil-structure seismic interaction analysis developed in the last decades together with designing the nuclear-electric plants on soils that are not rocks (V_s [1100 m/s), in this situation the seismic response being significantly influenced by the dynamic behavior of the massive soil on which these are situated.

The rigor of the soil-construction interaction analysis at seismic actions is related to the correctness of modeling the system formed of structure and massive soil, to the accuracy of the values assigned to the parameters defining the seismic excitation and to the physical-mechanical properties of the soil. Although still affected by uncertainties, the soil-structure seismic interaction analysis registered worldwide



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remarkable progresses in formulating the calculation models for exactly defining the seismic excitation and correct evaluation of the dynamic characteristics of the massive soil. Researches made in this field developed considerably and knowledge is now at a very advanced stage. Lately we know a tendency to implement the seismic analysis on stochastic models in practice of designing the nuclear-electric plants this allowing not only more rigorous grounds in defining the seismic excitation and the structural response, but also a quantification of the seismic risks of structural injury.

The soil-structure seismic interaction analyses tend to extend to conventional constructions, special as far as concerns their characteristic and importance, as well as the foundation conditions. Theoretical and experimental investigations made lately approach a series of aspects where the soil-construction seismic interaction effects can be significant and for which the current approaches are not satisfactory: buried and partially buried structures (special constructions, tunnels, pipe, etc) flexible foundations and pile foundations, seismic pressures on substructures walls etc. It is obvious that these researches will continue in the future with favorable effects on the improvement of the results accuracy obtained following the soil-construction seismic interaction analysis, this posing an interest especially for the special constructions where it is appropriate to use this application in the design process.

For the current constructions, the soil-structure seismic interaction analysis is not common for the design practice. At this moment it was created a high disparity between the knowledge stage at the research level and knowledge of the engineers in practice, designers of the conventional, current constructions.

In order to promote the practical application of the evaluation procedures for the effects of the soil-construction seismic interaction, the design engineers should be convinced about the necessity to evaluate these effects. The evaluation procedures must become an integrating part of the global soil-construction seismic interaction analysis and the designing process.

The design codes for current constructions, based on the behavior of a system with one degree of dynamic autonomy, introduces as result of the soil-construction seismic interaction only an increase of the oscillating period and of the damping for the fundamental module of the structural system, neglecting the introduction of other significant effects (dispersion of the input seismic motion, nonlinear etc.). This way the codes does not promote correct evaluation procedures for the soil-construction seismic interaction in the designing process. It is enough to demonstrate its importance. It is necessary to offer the designers simple and practical procedures in order to transfer knowledge, technical norms and adequate computer codes.



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3. ASCE STANDARD

In the ASCE 4-86 standard [1] are presented both the modeling and the analysis of the soil-structure seismic interaction phenomenon.

It is necessary to make soil-structure seismic interaction analyses for all the constructions that are not founded on rock. It is considered to be rock the soil for which $V_s / 1100$ m/s at $\gamma [10^{-3} \%$. If the construction is founded on rock, this it is considered as being the fix base structure.

For a structure to be able to function safely when is a sever earthquake, the ASCE 4-86 Standards [1] presents the following stage as being necessary in constructions design and execution.

1. Defining the seismic environment;
2. Performing an analysis in order to obtain the necessary information for design;
3. Designing alternative structural elements;
4. Execution technology of designed structures

When studying the soil-structure seismic interaction phenomenon it can be used both the direct method and the impedance function method.

In order to describe the spatial-temporal variation of the motion in free field, it is accepted the hypothesis of vertical propagation of the shearing and compression considering the twisting effects induced by the non-vertical propagation of waves, as well as the variation of amplitude and frequency with the depth.

When analyzing the soil-structure seismic interaction phenomenon we must consider the three-dimensional phenomenon of the radiating damping, together with the effect of the internal damping.

The non-linear behavior of the foundation soil can be approximated by the equivalent linear properties of the material. It is considered as being primer non-linearity, the nonlinear behavior of the material induced in the field by the seismic excitation ignoring the structural response. The secondary non-linearity it is considered as being the non-linearity induced in the field by the structural response as a result of the soil-structure seismic interaction phenomenon.

Generally, the structure-structure interaction is neglected. Exception from this rule is the retaining walls, indicated in standard, which, beside the elastic solution, must be considered also the active solution given by the Mononobe-Okabe formula [3].

The material flexibility effect for buried structure walls it is necessary to be considered in a soil-structure seismic interaction analysis.



The soil-structure seismic interaction phenomenon necessity and approach

The soil-structure seismic interaction phenomenon is governed by a series of uncertainties.

4. UNCERTAINTIES IN THE ANALYSIS OF THE SOIL-STRUCTURE SEISMIC INTERACTION PHENOMENON

The uncertainties that affects the soil-structure seismic interaction phenomenon are, usually, contained in two types of sources [4]:

- Uncertainties resulting from the incidental nature of the natural phenomenon – earthquakes - and of the materials properties;
- Uncertainties resulting from modeling the soil-structure seismic interaction phenomenon and from hypothesis adopted during studying the phenomenon;

The major uncertainties that affect the propagation phenomenon of seismic waves and that are not consistently reflected in the engineering practice are due to the following determinants:

- The input motion characteristics, including the seismic intensity, the propagation direction, its frequency substance ;
- seismic waves composition including: P and S depth waves, Rayleigh and Love surface waves, other kind of waves;
- spatial-temporal variation of the seismic move with the depth and distance including the seismic move incoherence and the effects of wave group passing;
- the nonlinear and hysteretic behavior of the massive soil, as well as its stability;

As far as concerns the soil-structure seismic interaction phenomenon, uncertainties can be due to:

- the effects of seismic waves spreading or the cinematic interaction;
- dynamic characteristics of the soil-foundation soil-structure assembly, including the burying effects on the system rigidity and on radiation energy dissipation;
- nonlinear behavior of the structure, more or less ductile, including the rigidity deformation and the increase of amortization;
- the presence on local non-linearity situated at the surface of the foundation- soil contact interface;



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5. CONCLUSIONS

In the seismic analysis of structures, the dynamic soil-structure interaction can sensibly influence the structural response.

The rigor of the soil-construction interaction analysis at seismic actions is related to the correctness of modeling the system formed of structure and massive soil, to the accuracy of the values assigned to the parameters defining the seismic excitation and to the physical-mechanical properties of the soil.

For the current constructions, the soil-structure seismic interaction analysis is not common for the design practice. It is necessary to make soil-structure seismic interaction analyses for all the constructions.

The soil-structure seismic interaction phenomenon is governed by a series of uncertainties.

References

- [1] ASCE STANDARD 4 – 86 - *Seismic Analysis of Safety Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures*, Published by the American Society of Civil Engineers 1986.
- [2] BEREVOESCU, I.C. – *Efecte ale interactiunii seismice teren-structura la constructii ingropate si partial ingropate* – teza de doctorat – UTCB, 2000.
- [3] C 239 – 92 - *Indrumator tehnic provizoriu pentru calculul terenului de fundare al presiunii pamantului pe lucrari de sustinere si al stabilitatii taluzurilor si versantilor la actiuni seismice*, Buletinul Constructiilor vol. 3 / 1993.
- [4] GHIOCEL, D.M. – *Uncertainties of Seismic Soil – Structure Interactions Analysis: Significance, Modeling and Examples* – US – Japan Workshop on Soil – Structure Interaction, San Francisco, 1998.
- [5] IPCT S.A. BUCURESTI – *Contract de reglementare nr. 1156 / 1996 – Ghid pentru analize seismice cu considerarea interactiunii teren structura si a caracteristicilor dinamice ale terenului*, Septembrie 1996.
- [6] Roesset, J.M. – *A Review of Soil-Structure Interaction* LLNL Laboratory, California UCRL 15262, 1980.
- [7] SEED, H.B., IDRIS, I.M. - *Soil Module and Damping Factors for Dynamic Response Analysis*, Report EERC 70-10, University of California, Berkeley, 1970.
- [8] SEED, B., SCHNABEL, P., - *Soil and Geologic Effects on Site Response During Earthquakes*, Seminar on Seismic Microzoning, June 1976, Thessaloniki – Greece.



Synthesis of results and conclusions coming from two points bending fatigue test accomplished in Roads Laboratory of C.F.D.P. in last years

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Summary

To know the behavior of asphalt mixtures at fatigue is an important question because this problem is taken into account in a pavement design for certain traffic.

To support this research, the Roads Laboratory of C.F.D.P. has carried out a fatigue apparatus that test trapezoidal samples at two points bending fatigue.

This paper presents the running mode and results obtained from this apparatus and draw the conclusions obtained in the course of fatigue tests.

KEYWORDS: fatigue, two points bending, asphalt mixtures



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1. INTRODUCTION

The estimation of fatigue life of asphalt mixtures represents a problem of a great importance. This is taken into account in calculus of a pavement structure that could be dimensioned to resist at a higher traffic.

The wheels of motor vehicles that run on road exert loads like load-unload that, cumulated in time, could lead to appearance of degradation, very small even invisible at the beginning. Because of addition of effects, after a high number of cycles, the material from pavement structure loose its resistance, decay and thus the fatigue appear.

The tensile stresses that appear at the bottom of asphalt layers in time of traffic loads, act especially on bituminous mastic and they are that lead to appearance of tensile strains.

Because of repeated loads, it is being initiate cracks and propagates in layer at the same time with traffic intensification finally leading at fatigue failure of pavement.

These degradations of pavement structures resulted from repeated load of bituminous layers are very important. Consequently it is necessary that bituminous material be studied and tested in laboratory with the aim to minimize the effects of fatigue during service.

In order to obtain these effects, the real state of stresses and strains in a pavement structure for repeated loads is simulated in laboratory. The cyclic fatigue tests are accomplished either under the constant stress or constant strain, or under the constant dissipated energy or even under different amplitude loads.

Thus, it will be established the fatigue behavior of this asphalt layers taking into account the climate conditions and the mixture composition. Because of the climate conditions of our country that are characterized by both high values of temperature during the summer and low values during the winter, the mixture must be designed to have a good behavior at both high temperatures and low temperatures.

2. THE FATIGUE TEST

Our specification in force stipulate that for fatigue characterization of a hot rolled asphalt it must be accomplished the indirect tensile test that carried out under constant stress and must verify the fatigue resistance either by number of cycles till cracking or by permanent strain at fatigue (300 pulsations).

It is known that (Doan, 1977):

- the thin asphalt layers (< 6 cm) are submitted to a constant strain;
- the thick asphalt layers (> 15 cm) are submitted to a constant stress.



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Consequently, the behavior of hot rolled asphalt at a fatigue test under constant strain not under constant stress should be studied.

Following the up-specified things, 8 years ago, in Roads Laboratory C.F.D.P. of our University was carried out a fatigue apparatus that test trapezoidal samples at two points bending, like L.C.P.C. fatigue apparatus, France.

In time, the apparatus has been submitted to consecutive improvements so that now we have an exact apparatus that supply useful information according to fatigue behavior of asphalt mixtures.

The principle scheme of apparatus is in figure 1. It is assisted by a computer, the work frame being those from figure 2.

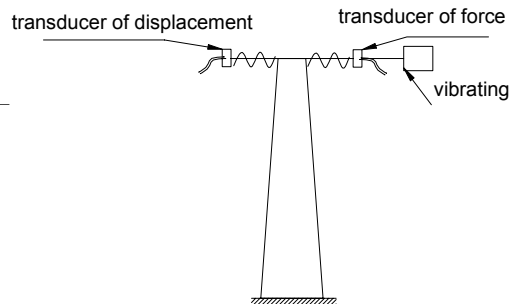


Figure 1. The principle scheme of fatigue apparatus

This fatigue apparatus test trapezoidal samples with the dimensions from figure 3 at continuous sinusoidal constant stress that acts at the free end (the top) of sample (figure 4).

The trapezoidal samples of asphalt mixture are cut from plates compacted by "Kneading Compactor".

The deformation being keep constant during the test, the force that result and is recorded at the free end of sample, will continue diminish with number of cycles.

The test is finished when the applied load result - the force - reached the half of its initial value.

Beside that, the fracture criterion is an arbitrary one it must be said that spreading of dates resulted from this kind of fatigue test is high, the fatigue life is generally high, the effect of mixture variable is low, and the effect of rest period is low and presents a rate of crack propagation more illustrative according to in situ conditions.



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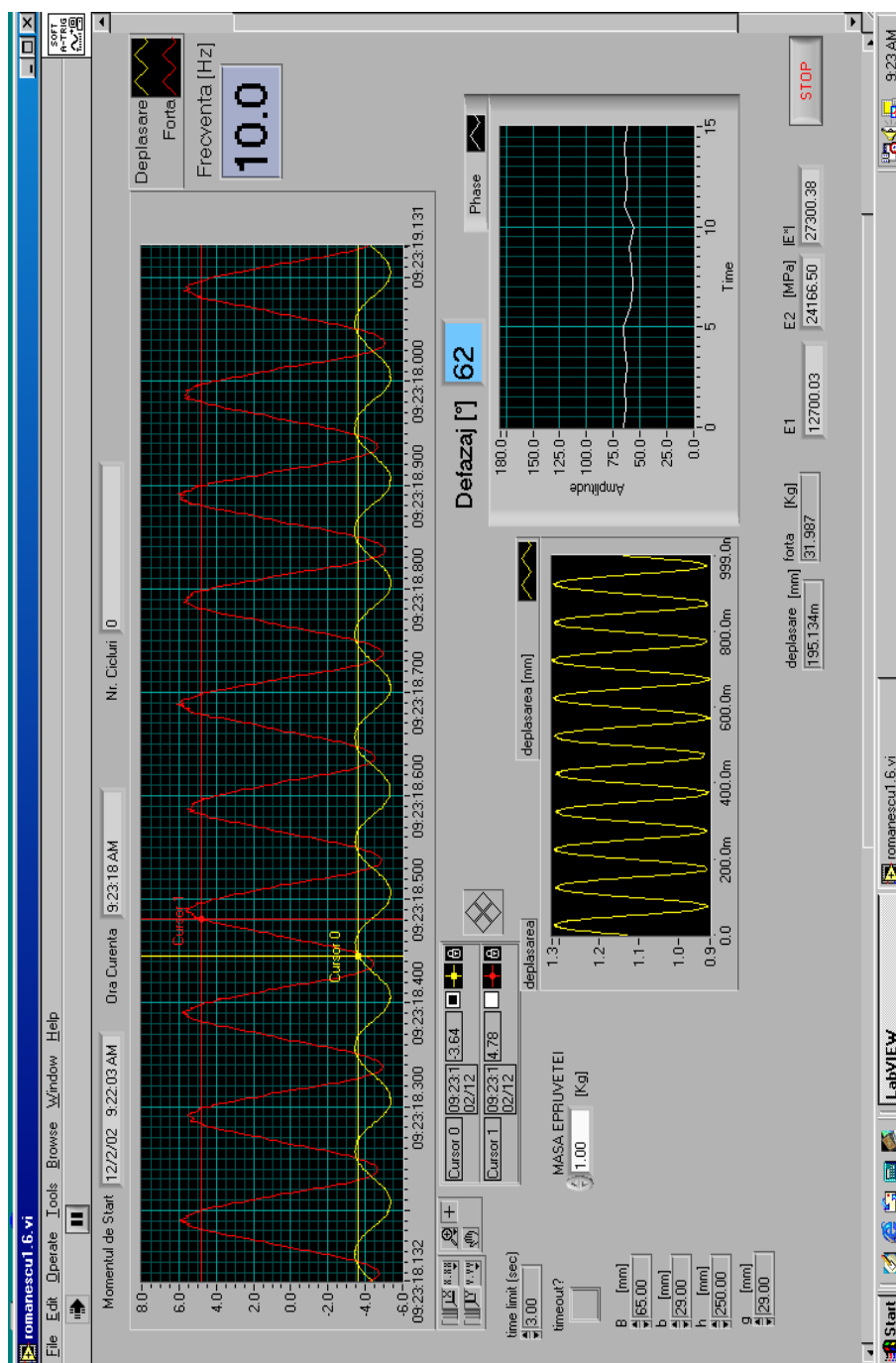


Figure 2. The work frame of fatigue apparatus

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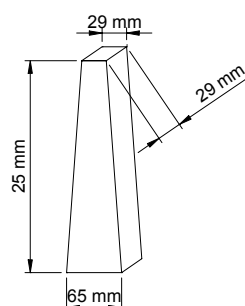


Figure 3. The dimensions of trapezoidal sample tested at fatigue

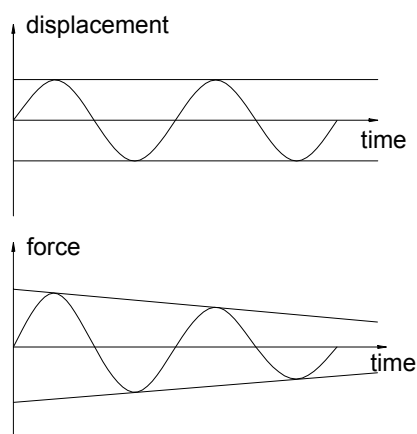


Figure 4. The load and response in the case of fatigue apparatus for two points bending

The asphalt mixtures are viscoelastic materials; their viscoelastic behavior is mainly determined by the presence of binder. The properties of the materials with hydro carbonated binder depend on temperature and rate of applied loading. They are characterized by the magnitude called complex modulus, E^* .

The complex modulus defines the stress-strain relationship for a linear viscoelastic material that is submitted to sinusoidal loads. When a sinusoidal stress is applied on a certain sample of asphalt mixture then the resulting strain comes with a delay because of phase angle, δ .

If the sinusoidal stress is $\sigma = \sigma_0 \sin \omega t$ (σ_0 – the stress amplitude, ω – the angular velocity) then the resulting sinusoidal strain is: $\varepsilon = \varepsilon_0 \sin(\omega t - \delta)$ (ε_0 – the strain amplitude, δ – the phase angle).



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The complex modulus (relation (1)) is: $E^* = E_1 + iE_2 = |E^*| e^{i\delta}$ (E_1 – the real part or elastic part, E_2 – the imaginary part or viscous part, $i^2 = -1$):

$$|E^*| = \sqrt{E_1^2 + E_2^2} = \frac{\sigma_0}{\varepsilon_0} \quad (1)$$

From the fatigue test by two points bending can be studied the rheological behavior of asphalt mixture by determine the complex modulus, elastic modulus and viscous modulus. The phase angle that appears between the applied load (deformation) and the response (force) is continuously recorded in function of number of applied cycles.

The relationships for the calculation of the complex modulus components and for the complex modulus norm (relations 2, 3, 4) are the following:

$$E_1(\omega) = \frac{1}{\gamma} \left(\frac{F_0}{f_0} \cos \delta + \mu M \omega^2 \right) \quad (2)$$

$$E_2(\omega) = \frac{1}{\gamma} \left(\frac{F_0}{f_0} \sin \delta \right) \quad (3)$$

$$|E^*(\omega)| = \frac{1}{\gamma} \left[\left(\frac{F_0}{f_0} \cos \delta + \mu M \omega^2 \right)^2 + \left(\frac{F_0}{f_0} \sin \delta \right)^2 \right] \quad (4)$$

where: F_0 – resulted force amplitude

f_0 – applied deformation amplitude

ϕ - phase angle between effort and deformation

M – sample mass

ω - pulsation

$1/\gamma = 166,52 \text{ cm}^{-1}$, coefficient that depends on the specimen dimensions

$\mu = 0,1206$, mass factor.

3. RESULTS

In last years in Roads Laboratory of C.F.D.P. has been carried out two points bending fatigue tests on trapezoidal samples made by different types of asphalt mixture for wearing course. The used materials for recipes was generally Chileni coarse and small crushed rock 8/16, 4/8, Chileni crushed sand 0/4, Basarabi limestone filler, Suplacu de Barcau bitumen 60/80, 80/100, Arpechim bitumen 60/80, ESSO bitumen 50/70, Viatop 80 plus and Tehnocel cellulose fiber, PNA



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fiber and glass fiber. The tests were carried out at different temperature from -10°C to 25°C and at two frequencies: 25 Hz and 10 Hz.

The fatigue results can be materialized in graphs like those presented in figure 5, 6, 7.

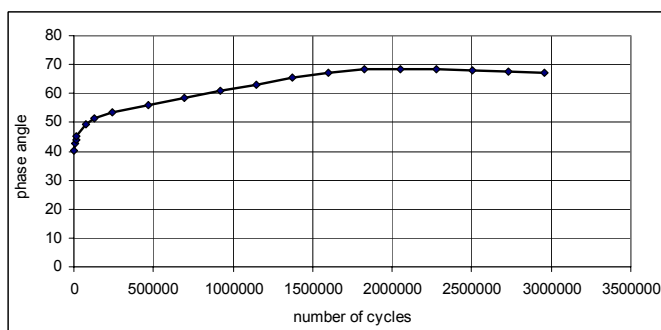


Figure 5. Phase angle versus number of cycles in the case of asphalt mixtures

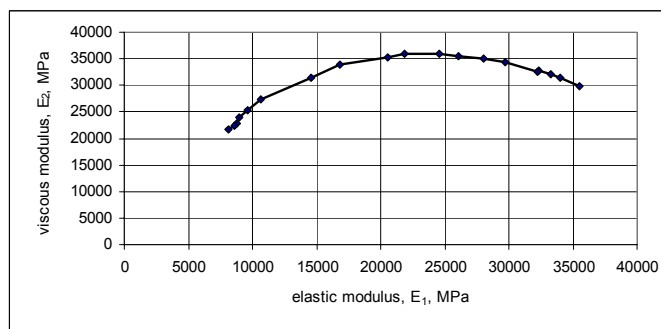


Figure 6. COLE-COLE diagram in the case of asphalt mixtures

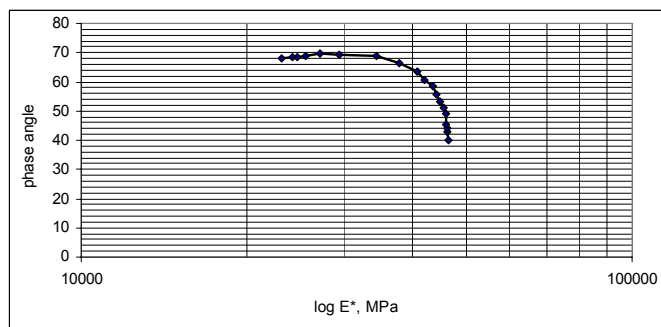


Figure 7. BLACK diagram in the case of asphalt mixtures



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4. CONCLUSIONS

From the vast quantity of conclusions supplied by the fatigue studies of asphalt mixture, as a result of analysis synthesis, the following can be drawn:

- the complex modulus value diminishes if temperature rise and frequency decrease. The complex modulus value is close by resilient modulus at low temperature;
- the complex modulus value is influenced by bitumen percent. If bitumen percent rise, the effect of temperature becomes important and the complex modulus value will be less affected by frequency;
- the phase angle value depends on temperature, rising with this and decreases with frequency. Also, phase angle rise with the thick of bitumen film that cover the aggregate;
- the phase angle obtained on studied asphalt mixtures is generally under 15 grades;
- the asphalt mixture behavior at negative temperatures depends on deformability potential of mixture;
- at negative temperature (-7°C), the mixtures have a close behavior, being hard to differentiate them in function of bitumen type or fiber type; the grouped together value of phase angle indicate a pronounced elastic character;
- in the case of materials with rheological behavior like bituminous mixture are, temperature is an important factor concerning the strains response of a layer submitted to a stress;
- at positive temperature (25°C) better results at fatigue can be obtain when asphalt mixture contain Arpechim bitumen;
- the mixture with a lower percent of crushed rock has a better behavior;
- the maximum fatigue life appears for a bitumen percent that give the maximum stiffness of mixtures;
- the phase angle is correlated to number of fatigue cycles according to a power function for an asphalt concrete BA16: $y = Ax^B$ and a second order polynomial function for an anti-rut asphalt mixture: $y = Ax^2 + Bx + C$ (with y - phase angle, x - number of cycles);
- the phase angle is correlated to $\log(\text{complex modulus})$ according to a second order polynomial function: $y = Ax^2 + Bx + C$ (with y - phase angle, x - $\log(\text{complex modulus})$); according to same function is correlated the viscous modulus to elastic modulus, too (with y - viscous modulus, x - elastic modulus);



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- for the thin asphalt layers it is recommended the accomplishing two points bending fatigue test.

References

1. Romanescu C., Răcănel C., *Comportarea mixturilor asfaltice antifagas la oboseala*, Buletinul Stiintific al U.T.C.B. nr. 3/2003.
2. Romanescu C., Răcănel C., *Studiul influentei curbei granulometrice si a tipului de bitum pentru mixturile asfaltice antifagas*, Zilele Academice Timisene, 2003.
3. Romanescu C., Răcănel C., *Caracteristicile reologice ale mixturilor asfaltice cu fibre de celuloza*, Al XI-lea Congres de Drumuri si Poduri, Timisoara, 2002.
4. Romanescu C., Răcănel C., *Comportarea mixturilor asfaltice cu fibre la temperaturi negative*, Zilele Academice Timisene, 2002.
5. Romanescu C., Răcănel C., *Complex Modulul and Phase Angle - Main Parameters to Characterize an Asphalt Mixture from Rheological Point of View*, Euraspalt&Eurobitume, Barcelona, 2000.
6. Romanescu C., Răcănel C., *Comportarea la oboseala a unor mixturi asfaltice performante*, Conferinta "Tehnologii moderne in constructii", Chisinau, mai 2000.
7. Romanescu C., Răcănel C., *Evaluarea modulului complex si a unghiului de faza pentru o mixtura asfaltica tip BA16*, Simpozion "Reabilitarea drumurilor si podurilor", Cluj Napoca, 1999.



Asphalt concrete mixtures design for high performance

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Summary

In the condition of improving Romanian legislation by European norms, concerning the design of premium asphalt (polymer modified asphalt, stone mastic asphalt, etc.), it appear the necessity of extending the laboratory tests. In this context, starting with the "Second rehabilitation program of the National road network " the National Road Administration, imposed for the carriage way to be designed with fibers (SMA or Masf 16 –Romanian Norm) and in this context to be tested in Wheel Tracking Test device, to anticipate irreversible cumulated stress along the life cycle period under estimated traffic. Considering the fact that at the date of starting the rehabilitation programs the method was not standardized, most of the contractors find it self in the situation of waiting for its job mix formula to be tested in the only existing Wheel Tracking Test at that date in the CESTRIN laboratory.

In the paper the author describe a new laboratory wheel tracking sample compaction method and the necessity of generalization the Wheel Tracing Test to all the National and Regional Road laboratories in Romania.

KEYWORDS: design mix formula, equipment, mechanical properties, mixture design, performance testing, standardization, vibrating compaction.



Asphalt concrete mixtures design for high performances

2. GENERAL REFERENCES

The transport infrastructure in general and road infrastructure in particular is responsible for socio-economic development of a society. The transport distribution of merchandize and peoples as indicators today and in the next future, sows as present a 78% with an increase rate near to 90% for the year 2005 from the total amount of transport.

In Romania the goods transport represent 87% comparing with the peoples transport indicator, which represent 85%, with a continuous increase in the next years.

The total length of the Romanian road infrastructure is 153 319 km. The national roads, represent 14 483 km included 113 km of motorways.

Comparing with other European countries, one of the principal quality indicators on public roads, such as, the density of public roads of 0.64 km/km², the length of motorways (113 km) and the number of km on public roads with modern pavements per 1000 inhabitants is about 1.98 km/1000 inhabitants, situate Romania on one of the last places.

The traffic is in a continuous amount, for example in the period 1990 – 1998 the number of vehicles per 28 hours increase from 3221 to 5900 vehicles /24 hours and a estimation for 2005 should be with 3000 more vehicles / 24 hours, compeering to year 1990. The main problem which generate the actual state of the public roads consist on lack on financial resources with the consequence of very low volume of maintenance works, the choice of inadequate technical solutions for pavement maintenance, on most of the road network, the lack in Romanian norms. The uncomfortable steady state of the public roads combined with the traffic amount, determined the National Road Administration to promote a series of programs to improve the state of the national network as well to improve the moralization and standardization..

2.1 The national road rehabilitation Romanian programs.

The Transport Ministry launches in 1991 “The national road rehabilitation Romanian programs” high priority the European class national roads, opened to international traffic, to ensure a very good connexion to European network. The program was assigned by local government with financial institutions such as IBRD, EBRD and EIB, ISPA, PHARE and others, with several objective such as:

The national roads rehabilitation providing the first 1031 km of modernizations and reinforcement ;

The modernization of adjoins and customs;

The safety of the traffic;



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Equipments and materials;
Consultancy;
Continuous education.

The main objective for those works was, the increasing of the resistance for the pavement to improve the load axel from 10 t to 11,5 t, the classification of the bridges in "E" class, the improvement of the geometric elements, the third lane construction for heavy traffic, the collecting and evacuation for pluvial water.

National Road Administration started, beginning with 1995, the negotiations for a new rehabilitation program, with IBRD, EBERD and IEB between 1997 – 1998.

The selection criterions for the second rehabilitation project was :

the internal rentability ratio;
the estimation of the future traffic and complex modulus;
cost estimation;
the analyze of the optimum way;
the identification of the edge properties.

According to the technical; specifications, for bid acceptance, in the feasibility study was provided the minimum technical requirements to improve the level of the road, specking about the road capacity, according to the estimated traffic, to ensure a minimum 7 m as wide, with a minimum of 1,5 m shoulders wide. Such a program involve many others aspects :

The identification of the contracts are as follows:

EBRD loans.

C101 – DN13, km 0+765 km 36+300, L = 35.535 km;
C102 – DN13, km 36+300 – km 86+400, L = 50,100 km;
C103 - DN13, km 86+400 – km 111+600, L = 25,200 km;
C104 – DN13, km 117+750 – km 165+930, L = 48,100km;
C 105 – DN15, km 5+000 – km 39+500; L = 34,500 km;
C106 – DN15, km 39+500 – km 69+970, L = 30,470 km.

Total EBRD L = 223,985 km.

IBRD loan.



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The contracts with EBERD loan:

C101 – DN13, km 0+765 – km 36+300, L = 35,535;

C102 – DN13, km 36+300 – KM 86+400, l = 50,100;

C103 – DN13, km 86+400 – KM 111+600, l = 25,200;

C105 – DN13, km 117+750 – km 165+930, L = 48,180;

C105 – DN15, km 5+000 – km 39+500, L = 34,500;

C106 – DN15, km 39+500 – km 69+970, L = 30,470;

Total EBERD L = 223,985 km.

IBRD loan.

C201 - DN6 km8+500 – km 51+000, L = 42,500;

C201 – DN6, km 51+000 – km 85+500, L = 34,500;

C203 – DN2, km 55+900 – km 105+000, L = 49,100;

C204 – DN2, km 105+000 – km 152+500, L = 47,500;

C205 – DN65, km 3+900 – km 21+200, L = 17,300;

C206 – DN65, km21+200 – km 49+000, L = 27,800;

C207 – DN65, km54+000 – km 90+000, L = 36,000;

C208 – DN65, km90+000 – km 115+000, L = 25,000;

DN 65B, km 0+000 – km 7+400, L = 7,400;

C209 – DN1, km 88+515 – km 111+000, L = 22,485.

Total IBRD L= 309,585 km.

IEB loan

C301 – DN1F, km4+900 – km 36+000, L = 31,000;

C302 – DN1F, km 36+000 – km 81+250, L = 45,250;

C303 – DN1F, km 89+800 – km 123+012,

C304 – DN19A, km 0+000 – km 48+000, L = 48,000.

Total IEB L = 157,562 km.

The total length of the second rehabilitation project was 691,132 km.



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On most of the above contracts the National Roads Administration impose to designers and contractors to apply Stone Mastic Asphalt as wearing coarse. In this stage the necessity of Wheel Tracking test was imperious.

2.2 The history of the quality assurance in National Road Administration.

The quality assurance politic in NAR was applied under national laws, but was considered also for promoting and checking the new technologies through the CESTRIN unit. Starting with 1995 the quality assurance and control structure was defined under the ISO 9000 standard.

The quality system, implemented between 1995 and 1996 was reconsidered after the externalization of execution units from NAR. The responsibilities of contractors on the national network were established in accordance with legal providing as follows:

- the designer, for technical documentations for lever of quality, according to the level of interest;
- the contractor, for technologic execution of the works, according to the technical documentation, internal quality control in its own quality system, (technical responsible with execution, authorized laboratory, etc.);
- the consultant for confirming the quality of the works, to eliminate the unconformities.

The NAR quality control acts through some compartments such as ACQ and authorized laboratories and CESTRIN laboratory. Through the NAR ACQ compartment is executed a exterior quality control without legal substitution of the responsibilities for the participants to the execution process, to eliminate as soon as possible the unconformities.

3. THE PREPARATION OF THE ASPHALT CONCRETE MIXTURE SAMPLES USING THE VIBRATORY ACTION AS A NEW PROCEDURE

It is in fact unique in Romania that we use to prepare the Wheel Tracking samples a vibratory device developed with the help of an laboratory equipment Romanian producer.

The procedure start with the preparation of the □ 100 mm and 61 mm thick asphalt concrete sample, in the idea to find a correlation with the Marshall design procedure. I used a vibratory plate with the amplitude velocity 300 rad/sec, the □ 101.1 mm Marshall cylinder and an static load over the piston of 13,300 kg.



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The asphalt in the correct quantity was pored in the cylinder at the temperature of 160– 170 0C and start the vibrating procedure using time intervals of 5 min, 7 min and 9 min.

The same asphalt grading samples was prepared using Marshall hammer to have an correspondence characteristics. All the six samples were introduced in water at 60 o C 45 minutes before determining the Marshall stability. The results are in the next table with the mention that the first samples are prepared with the vibratory procedure and the next three with the Marshall design process.

Table 1. The data Asphalt Concrete Mixtures Characteristics

Sample nr.	Asphalt concrete mixture characteristics					Characteristics	
	Diameter (cm)	Thick (cm)	Weight air (g)	Weight water (g)	Density (g/cm ³)	Marshall stability S (kN)	Marshall deformation I (mm)
1	10,17	6,36	1107,7	614,4	2,144	6,00	5,62
2	10,16	5,46	1002,0	566,2	2,264	4,80	6,10
3	10,16	5,44	998,4	559,6	2,268	4,72	6,35
4	10,13	5,94	1118,0	641,3	2,335	8,70	5,70
5	10,12	5,9	1114,0	638,7	2,347	8,50	5,90
6	10,12	5,91	1113,3	636,2	2,342	8,60	5,72

The graphic representation is as in the next figure:

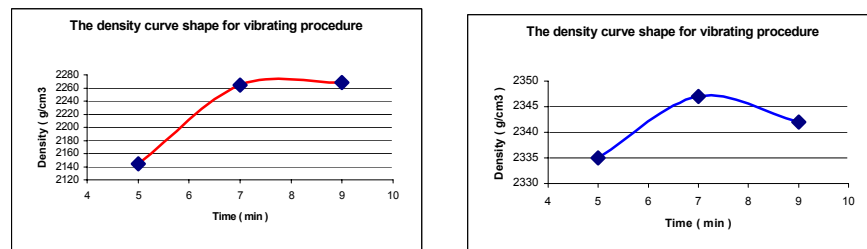


Fig. 1 The evolution of the density of tested samples by time

The conclusion observed from the above table is that for both the procedures there is a maximum attained, referring to the maximum performance for the same mixture with the recommendation of improving the compaction characteristics for



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the vibrating procedure. This recommendation was taken in to consideration for the next step referring at a 300 x 300 x 40 mm plate sample preparation for Wheel Tracking Test.

I used the same vibrating device, a mould with the dimension of 300 x 300 x 70 mm and a metallic piston with the total weight of 50 kg. I calculate the quantity of the asphalt concrete mixture (8532 g) to obtain after the compaction a plate with the dimensions 300 x 300 x 40 mm and a minimum density (2300 g/cm^3) request by standard (STAS 174-1-2002) for the chosen formula.

I prepare three plates compacted the first, during 10 minutes, the second during 20 minutes and the last during 30 minutes.

The results are in the next table:

Table 2 The data characteristics for asphalt density.

The asphalt concrete mixture samples characteristics						
Sample nr.	Side 1 (cm)	Side 2 (cm)	Thick (cm)	Weight air (g)	Weight Water (g)	Density (g/cm ³)
1	28	30	4,511	8399,8	4633,0	2,216
2	28	30,15	4,3	8371,0	3901,0	2,306
3	28	30,20	4,28	8342,2	3839,0	2,306

The shape of the asphalt density curve look like in the following draw.

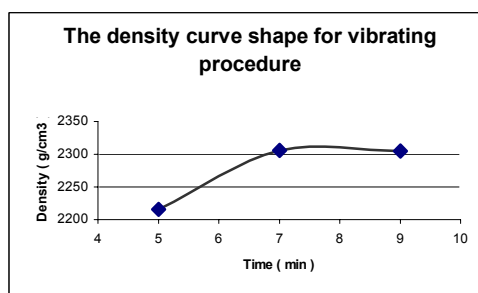


Fig. 2 The density variation draw.

There are some advantages using this procedure for samples prepare. One refer to the shape of both faces, which are plane with ought any irregularities. The other refer to the simplicity and the duration of the procedure.



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4. THE DETERMINATION OF THE WHEEL TRACKING RATE

4.1 Theoretic requirements.

The rut obtained on laboratory conditions, meant, the thickness reduction of an asphalt mixture sample of 30x30 cm plan size under the frequently effect of a rubber tire wheel, loaded with a required mass.

By execution, the wheel tracking device have a few variable. These are :

the time norm lasting the test'

temperature estimated on control chamber;

wheel load.

Time norm.

On laboratory practice and also on theories developed till now are provided 3 patterns time intervals 30-45 min.; 75-90 min. and 105-120 min. As result of different studies executed on several world laboratories, has been noticed that is more realistic, on deformation level estimation, to determine the speed according to a time of 15 minutes till the end of test. It has been noticed that the frequently pass effect, the 1st period of time is according to sample consolidation and is irrelevant for rut measurement. By attaining the sample consolidation moment, in the same way it happened with the vehicle tire action in reality, the strain stress state cumulated in the asphalt layer generate ruts. This moment wants to be identified by laboratory tracking test procedure.

Temperature estimated on control chamber.

The temperature represent another variable. According to British standard the testing temperature was established at 45 °C. Considering the "Climatic Romanian Map" there are two climatic areas along the Romanian territory. One correspond to hot climate and the other to cold climate. The Romanian norm established two testing temperatures one for 45 °C and the other for 60 °C, The 60 °C testing temperature is more appropriate for premium asphalt such as SMA or Polymer modified asphalt.

c. The wheel load.



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The wheel load is according to traffic. The B.S. standard introduced the 520 N load at the tire sample contact interface. According to several other studies, this load can be modified with other values.

The limits according to Romanian norm for wheel tracking rate and the rut are in the next table.

Table 3. The data Wheel Tracking Rate values

The average nr.of vehicles	The wheel tracking rate (mm/h.) max..		The rut value, (mm) max.	
	45°C	60°C	45°C	60°C
< 1500	6.0	8.0	6.0	9.0
1500 – 3000	4.0	6.0	5.0	8.0
3000 – 6000	2.0	3.5	4.0	7.0
> 6000	<2.0	<3.5	<4.0	<7.0

4.2 Practice application.

The test was performed according to AND 573/2002 norm which is according to BS 598 /96 “Sampling and examination of bituminous mixtures for roads and other paves areas”.

The interval of testing was set up at 45 minutes and at a temperature of 45 °C. In the last 15- th minutes I red the values of rut as in the following table:

Table 4. The readings characteristic.

Minute	□	Interval
30	0,34	n-3
35	0,49	n-2
40	0,58	n-1
45	0,73	n

The deformation rate was calculated using the following formula:

$$V_{dm} = -12\Delta r_{n-1} + 12\Delta r_n = -12 * 0,58 + 12 * 0,73 = 1,8 \frac{1}{10 mm} \quad (1)$$



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$$V_d = 10,4 * V_{dm} * \frac{w}{L} = 10,4 * 1,8 * \frac{50}{520} = 1,8 \frac{mm}{h} \quad (2)$$

The value for Wheel Tracking rate of 1,8 mm/h resulted to be according to the minimum value provided by the standard for more than 6000 average number of vehicles. The job mix formula was well design and what is important to note, refer to the procedure of preparing the samples which is in fact a good method.

4. CONCLUSIONS

The wheel tracking test represent a very good solution for asphalt design under certain traffic volumes. It is also a very good way of testing on core sampling the correct application in situ for a certain job mix formula, to be a voluble instrument for the client to verify the quality level of the contractors.

This test was developed from the reason to make a very good laboratory association with the real traffic action along the road network. This is a good opportunity to encourage the Romanian laboratories to have its own Wheel Tracking Test device to give to National Road Administration an instrument to measure the repeatability and reproducibility of the results to improve the job mix formula for high performance asphalt concrete mixtures

References

1. BS 598/96 "Samplng and examination of bituminous mixtures for road and other paves areas".
2. NLT 173-84 "Resistencia a la deformation plastica de las mezclas bituminosas mediante la pista de ensaio de laboratorio".
3. J.E. Munoz, J.B. Sebastian " Parametros de caracterisation de las mezclas bituminosas ensayados en pista de laboratorio y su evolution con algunes modificaciones del ensayo".
4. AND 573/2002 " Norm concerning the rut susceptibility of hot asphalt concrete mixtures for road carriage way".



Rehabilitation of tramways and bridges in Timisoara

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Abstract

The paper presents some results of a small part of a large rehabilitation program applied both to tramways and to carriageways and bridges too. Typically for Timisoara town is the oldness of the crossing structures: 80 years old. The four bridges submitted to this process of rehabilitation are different regarding the statically structures and cross section too. It was necessary to redesign the gauge on the bridges and the oldest one needed consolidation. For the first time in Romania, for the fastening of the rail on the bridge, the system ICOSIT from Sika was adopted

1. GENERAL ASPECTS

The Timisoara city has the benefit of important external financing for the modernizing of its tramways. At the same time with these projects, the city hall of Timisoara is financing the rehabilitation of the streets affected by the works for the modernizing of the tramway and implicit that of the bridges, which assure the connection between these streets over the Bega channel.

Regarding this, we had the privilege to participate at the elaboration of the technical solutions for the redevelopment of the streets, as well in their geometry as also as road structure, of the bridges and of the underground network affected by the works for the rebuilding of the tramway platform. This meant the replacement and supplementation, where needed, with new capacities of the underground network (electrical, water-channel, natural gases, telecommunication, district heating).

In the actual state the streets, having 2 or 4 traffic lanes, have the carriageway made out of concrete asphalt (Revolutiei 1989 Av., Dr. I. Nemoianu str., A Saguna str., Calea Dorobantilor etc) or granite block pavement (Mihalache str., partially Dacilor str. etc).

The carriageways were designed in correlation with the specific environment and the road structure was adapted to the existing traffic and also to that in perspective.

The use of the granite block pavement on some streets is part of the architectonical concept regarding the arrangement of the Traian Square and the areas next to it.



A. Bota

solution, repairs at the pedestrian fence and the decorative elements if damaged by using a material which should regrant the structure the initial aspect (for the ancient bridges like Traian and Decebal), respectively its replacement at the other two bridges. For the protection of several areas of the bridge structure the choice of optimal qualitative solutions was aimed.

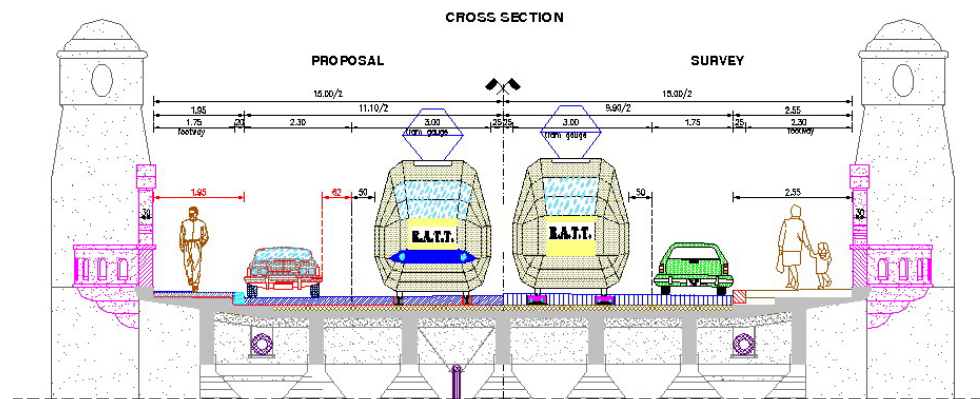


Fig.3 - Decebal Bridge

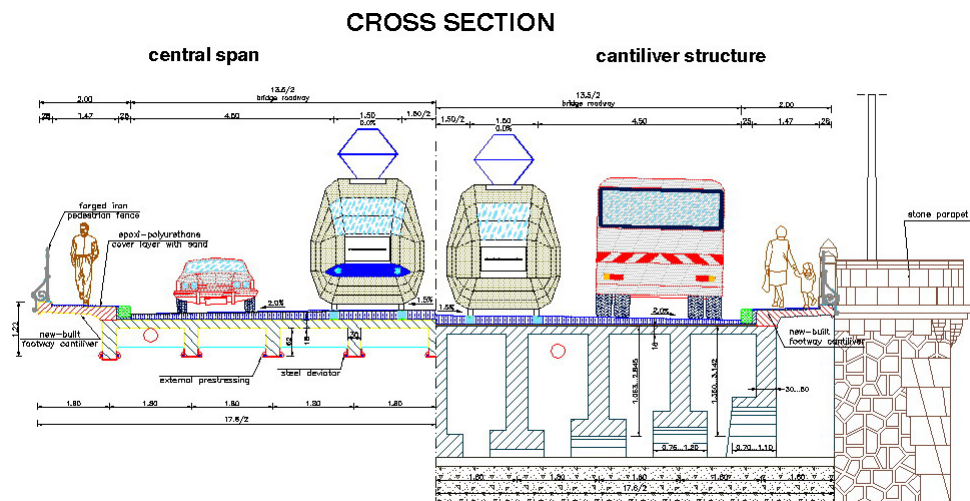


Fig.4 - Traian Bridge

The Traian Bridge has a limited bearing capacity due to the age as also because of the technical norms used at the time the structure was designed. These had stipulations regarding the loading values, which are much under those nowadays. The bridge is going to be consolidated by using external prestressing in order to



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satisfy the request of a higher loading class. Nevertheless the designs have to contribute to the maintenance of the architectural identity of the structure.

The aim, concerning the discussed bridges, was the rearrangement of the gauge (runway and footway) in order to correspond to the actual traffic conditions and in perspective, as it can be seen in fig.1 to 4.

3. REHABILITATION SOLUTIONS FOR THE DACILOR BRIDGE

Due to the existence of an incomplete technical documentation and new elements, which arose after the works have started, the elaboration of some particular execution details related to the real situation were assessed.



Photo 1 - Long view before of the starting of the works

The remove of the existing layers of the carriageway on the bridge has revealed a very irregular surface because of the deficiency at the placing of the precasted reinforced concrete plates which together with the steel girders form the mixt steel-concrete resistance structure (Photo 1, Photo 2, Fig. 5) .



Photo 2 - Cleaned concrete plate

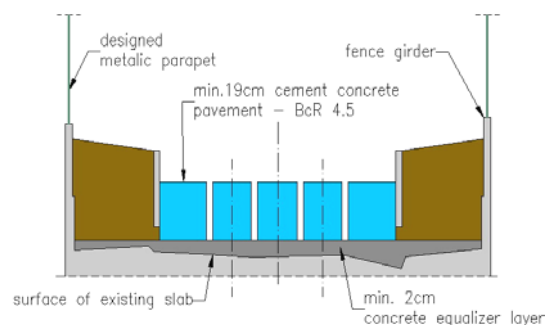


Fig. 5 - Transversal profile

A. Bota

The execution of an equalization concrete layer in order to obtain a surface proper for the application of the waterproofing system but also for the execution of a curb in a vertical plane, an outcome of the redesigning of the longitudinal profile, became imperative (Photo 3).



Photo 3 - Equalization concrete layer



Photo 4 - Existing retaining wall

When the transition plates were brought down, a reinforced concrete frame with a retaining wall, most probably a remainder from the structure of the old bridge, could be seen (Photo 4).

The structure for the new retaining wall is based on this structure and will also support the designed transition plates (Photo 5).



Photo 5 - New retaining wall



Photo 6 - The steel structure corrosion

Because the corrosion attempt a high level (at only 15 years old), it was necessary to “clean” the steel structure with a performant and ecological system, based on water extra high pressure. Sika provides the multilayer anticorrosive treatment.

The solution for the superior layer on the footway consisting of using epoxi-polyurethan lining and also quartz-sand allows the obtainance of good waterproofing of the concrete in the footway and furthermore an asperity having an efficient non-slipping effect. It also permits the coloring of the pedestrian area.



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Photo 7 - Anticorrosive treatment on the girder and at the end of the bridge

The transition between the superstructure of the bridge and the reinforced concrete plate of the tramway respectively the carriage way structure of the adjacent streets, is going to be realized by the means of special transition plates designed in correlation with the existing situation (bridge with cantilever and retaining wall).

4. REHABILITATION SOLUTIONS FOR THE MIHAI VITEAZU BRIDGE

The works for this bridge had the same starting conditions as the Dacilor Bridge (incomplete initial technical documentation etc). The Mihai Viteazu Bridge is realized with four traffic lanes on two parallel superstructures separated by a longitudinal joint.



Photo 8 - View before the works started

Photo 9 - Cleaned concrete plate

In this situation the rehabilitation works were possible alternatively on each superstructure. The traffic was guided, in the mean time, on the other superstructure, which was not affected by the works (before, respectively after the rehabilitation) (Photo 8, Photo 9).



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The remove of the existing layers revealed a very neat monolith plate, having only few geometrical imperfections. In contrast to the basic documentation, it has been found that, in the tram rail area the plate was made as a “small channel”. As a consequence, the redesigning of the cross section and the renouncement of the paving concrete, was necessary and that made the choice of a much more versatile structure for the roadway possible.



Photo 10 - Damage in the pedestrian fence



Photo 11 - New fence girder

Due to the degradation of the concrete from the guard beam on large surfaces and in depth, respectively of the steel structure from the pedestrian fence, the replacement of the pedestrian fence and its girder was disposed (Photo 10 & 11).

Concerning this structure, the execution of the equalization concrete layer was necessary only for the correction of the grade line, respectively the realization of the cross slope for the discharge of water.

At the same time the fence girder is being repaired and the existing reinforcement is being completed, the new geometries of the element being taken in account.

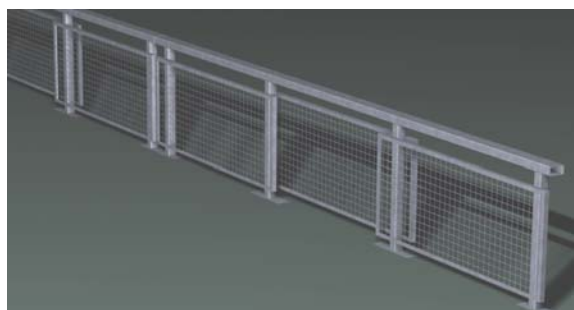


Photo 12 - Designed pedestrian fence

The existing fence will be demolished so that the steel profiles remain enclosed in the new realized concrete girder. In that way they become connectors between the cantilever of the footway and the fence girder. The new designed fence is thought as a modulated steel structure, protected by zinc coating, presenting itself with a

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high transparency, considering the fact that it can respond entirely to the standard stresses (Photo 12).

5. THE TRAMWAY ON THE BRIDGE

In order to choose the optimal solution for the fastening of the tramway on the bridge (avoiding the perforation of the concrete plate of the bridge superstructure) a comparison was made between two systems: SIKA and ORTEC.

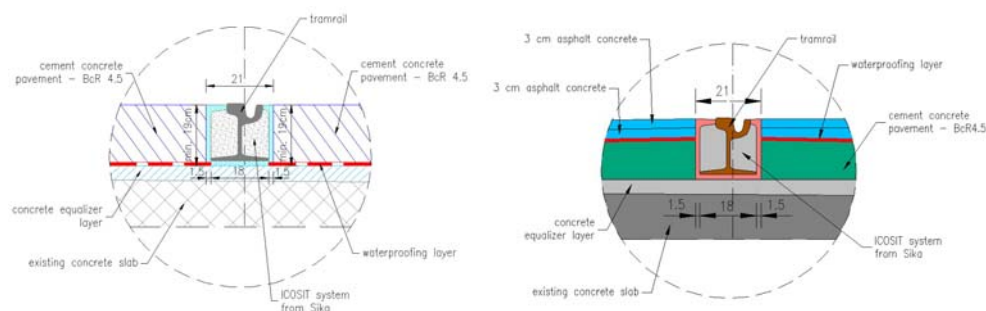


Fig. 6 – ICOSIT System on the Decebal Bridge and on the M. Vitezu Bridge

As a conclusion, in order not to affect the concrete plate of the bridge superstructure by using fastening solutions which involves new perforation of the concrete plate (ORTEC system used on the street), the SIKA system was adopted. This system consists in fastening of the rail on the bridge by using ICOSIT KC 340/45 (Fig. 6).



Photo 13 – ICOSIT System on the Decebal Bridge and on the M. Viteazu Bridge

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Nowadays the rehabilitation works of the two- presented bridges are in process aiming the fastening of the rail by using the ICOSIT system, as national premiere (Photo 13).

References

- [1] *** SC APECC SRL Timișoara, Consolidare Calea. Dorobanților și str. A. Șaguna. Podul Mihai Viteazu. Contract 369/2002.
- [2] *** SC APECC SRL Timișoara, Amenajări stradale str. M.Kogălniceanu. Podul Dacilor. Contract 423/2003.
- [3] *** SC APECC SRL Timișoara, Modernizare str.I.Nemoianu + str.Ferdinand + Blv 16Dec.1989. Podul Traian. Contract 446/2004.
- [4] *** SC APECC SRL Timișoara, Modernizare blv. Revoluției + str. Proclamația de la Timișoara + str. C. Brediceanu. Podul Decebal. Contract 498/2004.
- [5] *** STAS 10111/2-87 Poduri de cale ferată și șosea. Suprastructuri din beton, beton armat și beton precomprimat. Prescripții de proiectare.
- [6] *** STAS 2924-91 Poduri de șosea. Gabarite.
- [7] *** STAS 3221-86 Poduri de șosea. Convoaie tip și clase de încărcare.
- [8] *** STAS 1545-89 Poduri pentru străzi și șosele; pasarele. Acțiuni.
- [9] *** STAS 10101/OB-87 Acțiuni în construcții. Clasificarea și gruparea acțiunilor pentru podurile de cale ferată și de șosea.
- [10] *** FREYSSINET – Elastomeric bearing pads. Expansion joints.
- [11] *** SIKKA Partner der Bahn

