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EVALUATION OF THE SUSTAINABILITY OF FLEXIBLE PAVEMENTS

BY

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Abstract. Extreme natural phenomena as the effects of climate change have become a threat by increasing their frequency and magnitude, globally, implicitly, in Europe and Romania. In order to prevent and to mitigate the impact, society must adopt fair and effective measures. Regarding the road transport system that is of a fundamental importance to the country's economy and its potential development, new transport infrastructure must be sustainable and immune to the effects of climate change.

The sustainable road transport system includes pavements with a life cycle of more than 40 years, which are disaster resistant, without major degradation and loss of functionality and with a low environmental impact. The pavement sustainability assessment can be performed by using Life Cycle Assessment and Life Cycle Cost Analysis methods.

In this paper, considering the results obtained with the Romanian PD 177-2001 Normative, the Long Lasting and the Asphalt Institute, commonly worldwide used methods, the design of flexible pavements, based on sustainability criteria is considered and analyzed.

Keywords: infrastructure; impact; traffic; elasticity modulus; asphalt.

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1. Introduction

Under the pressure of the effects of climate change, of the technological and demographic explosion, one question arises: "What will be the price paid by the environment and future generations?". The international community has developed the answer under the form of the concept of sustainable development, without interruption, without loss of qualities, to a scale of time for dozens human generations, but on a space scale limited by the size of the Earth, which is a closed system (U.N. Report of the WCED, 1987).

The United Nations General Assembly from New York, in 2000 adopted the Millennium Declaration which identified sustainable development principles and agreements that include economic, environmental and social equity, also known as the sustainability pillars, which must be kept permanently in a sustainable balance (Dam *et al*., 2012).

In order to define a "safe operating environment for humanity" as a prerequisite for sustainable development, a central concept in the structure of the geo-system, namely the "boundaries of the Planet" approved by United Nations, was proposed on March 16, 2012 (Steffen *et al*., 2011).

A basic tool of the national economy is the transport system, but at the same time it is an important energy and lithological resources consumer as well as a greenhouse gas generator (Fig. 1). In this context, it is necessary to promote sustainable transport at European and World level.

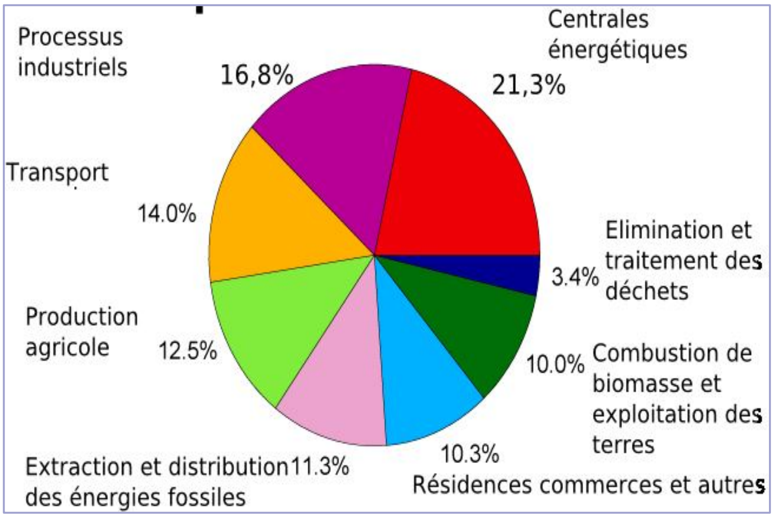

Fig. 1 – Greenhouse gas emissions, from 8 different areas, in 2000 (http://www.globalwarmingart.com/wiki/Greenhouse_Gases_Gallery).

For Romania, it is imperative to adopt the sustainable road transport system because it provides technical levels appropriate to the integration of the Romanian road network into the European transport infrastructure.

2. Sustainable Pavements

The sustainable pavement means pavements capable for reducing the social, economic and environmental impact. In the sustainable road transport system there is a balance between its components: the pavement management system, the road transport infrastructure and the rolling stock.

The sustainable management system emphasizes accelerating economic and social development in an ecological manner, and represents the way in which decision-makers translate into reality the principles of sustainability through specific measures. Related activities include strategies for road transport beneficiaries, technical and financial restrictions for vehicle emissions, funding of research programs.

Sustainable road transport infrastructure includes: sustainable durable pavements – with a life cycle of more than 40 years; robust pavements – disaster resistant, without major degradation and loss of functionality and with low environment impact.

The sustainable rolling stock includes the vehicles with improved structure and thermodynamic characteristics of optimized engines, or using other energy sources.

Designing geometric elements appropriate to current traffic requirements, increasing design speeds and ensuring the very good technical condition of the pavement surfaces lead to adequate provision of transport services and to the efficient servicing of material production (Andrei, 2003).

Knowing the technical condition of existing pavements, an objective analysis can be made by applying the primary functions of pavement management (planning, programming, preparing and performing operations), in which each function is associated with a repetitive process called ”pavement management cycle” (Andrei, 2003).

Environmental issues need to be anticipated, as any further analysis leads to costly solutions or compromise solutions.

According with the existing literature (NCHRP, 2011), pavement is considered to be sustainable if it fulfils the following conditions: achieves the technical goals for the road; preserves and restores ecosystems related to the road; makes effective use of natural, financial and human resources; meets the essential human needs (health, safety, equity, job security, satisfaction and comfort).

The main components of a sustainable transport system are presented in Table 1.

Table 1
The components of the sustainable transport system

The sustainable transport system		
The environmental component	The social component	The economic component
Increased durability	High safety	Low cost for execution
Low energy consumption	Improved aesthetics	Easy maintenance
Reduced GHG emissions	Low vehicle operating costs	Inexpensive rehabilitation
Noise attenuated	GHG emissions diminished	Low vehicle operating costs
Improved air quality	Easy access	Reduced costs in the event of an accident
High water quality	High mobility	

In relation with Table 1, the pavement durability can be characterized by the design lifecycle, service life, economic life and analysis life. Conventionally, the lifecycle of a pavement is considered to be linear, starting with materials production, design, execution, maintenance and ending with the replacement, recycling or rehabilitation. If the pavement is sustainable, all these life durations can be extended.

In defining and assessing the pavement sustainability, the environmental indicators have an important role to play in identifying problems, setting objectives, choosing between alternative options, anticipating the possible future effects of some actions.

The most significant environmental indicators related to the pavement system are: the fragmentation and the change of the habitats; the level of the greenhouse gas emissions and pollutants from the vehicles used for road construction and maintenance and the vehicles that traffic the road; the noise level produced by infrastructure construction and the traffic of the vehicles.

The positive social impact of the sustainable pavements is reflected in the fact that they ensure access and mobility of community members in daily activity, ensure the transport of goods and passengers, create jobs, facilitate business development.

3. Assessing the Sustainability of the Flexible Pavements

The sustainability measurement methods are evolving, based on various principles such as the quantification of the greenhouse gas emissions, the lifecycle assessment, the energy consumption and the consumption of the materials for the pavements.

Among the most well-known and used systems for assessing the sustainability of the pavements are the Life Cycle Assessment Method (LCA) and the Life Cycle Cost Analysis Method (LCCA).

3.1. Life Cycle Assessment Method (LCA)

The LCA method aims at analyzing and quantifying the environment impact on the pavements throughout their life cycle. The result is expressed in terms of energy consumption and greenhouse gas emissions.

The main steps of the LCA method analysis are:

a) the definition of the purpose and of the area: explicit formulation of the phases for the lifecycle under analysis;

b) inventory analysis of the environmental flow: quantification of inputs (materials, energy resources) and outputs (waste, pollution);

c) the environmental impact assessment over the life cycle: the expression of the inputs and the outputs of the system in equivalent CO_2 emissions.

The advantages of the LCA method consist in:

a) it is possible to identify opportunities to improve the environmental performance of the pavement during its life cycle;

b) it provides information to the decision makers, to prioritize and plan strategies;

c) it allows the selection of the indicators with the least impact on the environment.

3.2. Life Cycle Cost Analysis Method (LCCA)

The LCCA method refers only to the economic component of the sustainability, being "an analytical tool to provide cost comparisons between two or more alternatives that produce the same benefits for the project under consideration" (Dam *et al*., 2012).

If the benefits can be expressed in money, then they will be considered together with the costs. If there are other decision makers that cannot be turned into money, then environmental factors and social factors must also be considered.

4. Design Methods for Flexible Pavements. Sustainability analysis

The pavement design requires the identification of the site conditions: the climate type, the soil type, the hydrological regime, the number of the standard axles, the pavement type, and its design to achieve the desired performance (roughness, durability, safety, aesthetics).

The design influences the sustainability factors such as: the life cycle costs, the performance and the materials used.

The flexible pavement is designed such that the stress at the bottom of the asphalt layer is below the limit at which cracking begins.

Three structural design methods currently used will be analyzed from the perspective of sustainability.

4.1. The Analytical Method - Normative for Dimensioning of the Flexible and Semirigid Pavements PD177-2001

The PD 177-2001 normative is the basis of the design of the flexible and semirigid pavements, for both new roads and for the modernization or rehabilitation of several road categories in Romania.

For the design of the flexible and semi-rigid pavements, the structure of the pavement is established and the load status under the computing traffic is verified so that the following criteria are met:

i) for the flexible pavements: the specific deformation at the base of the bituminous layers and the specific deformation at the sub-grade level;

ii) for the semi-rigid pavements: the specific deformation at the base of the bituminous layers; the admissible stress at the bottom of the natural aggregates stabilized with hydraulic or puzzolanic binders layer, and the specific deformation at the sub-grade level.

The input data are the geotechnical characteristics of the foundation soil; the traffic data (composition, intensity, evolution) and the hydrological regime of the road complex (the type of the cross-section profile, the way of ensuring the surface water leakage, the drainage possibilities, the groundwater level).

The design phases provide: the establishment of the traffic, the determine of the load-bearing capacity at the sub-grade level, the composition of the pavement system, the analysis of the road pavement at the standard axle load and the establishment of the pavement system behaviour under the traffic.

Oversized structures, with a thickness between 75 and 95 cm, result because the elasticity modulus of the asphalt mixtures is low. The design life is quite small, around 15 years.

4.2. Long Lasting Flexible Pavements Method

The LLFP method innvolves the use of high quality materials such as Stone Matrix Asphalt (Andrei, 2002), asphalt materials with a higher elasticity modulus, which eliminates fatigue cracks, temperature variations, longitudinal grooves and surface damage. Flexible pavemets with lower thickness than the classic ones are obtained, but capable to resist to a higher computing traffic and frost resistant.

4.3. Asphalt Institute Method

The Asphalt Institute design method considers the pavement as a multi layer elastic system (www.asphaltinstitute.org). In design, different charts are used, that include traffic loads (expressed in 80 kN standard axles), the maximum stress at the bottom of the asphalt layer and the maximum vertical compression load on the subgrade surface.

The main design stages are given by the input data (resilient modulus, the computing traffic and the average annual temperature), the materials selection and identifying the minimum thickness of the layers using the specific calculation diagrams.

5. Conclusions

The Asphalt Institute and Long Lasting Flexible Pavement (LLFP) methods proved their superiority on classical method, by their environmental and economic advantages. PD 177-2001 method uses low elasticity modules for the asphalt mixtures, so the pavements are oversized. The asphaltic materials with a higher elasticity modulus lead to thinner layers, but to higher capacity to support a greater traffic.

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EVALUAREA SUSTENABILITĂȚII STRUCTURILOR RUTIERE FLEXIBILE

(Rezumat)

Fenomenele naturale extreme, ca efecte ale schimbărilor climatice, au devenit o amenințare prin creşterea frecvenței şi magnitudinii lor, la nivel Global, implicit, la nivelul Europei şi în România. Pentru preîntâmpinarea şi atenuarea impactului, societatea trebuie să adopte măsuri corecte şi eficiente.

Referitor la sistemul de transport rutier care este de importanță fundamentală pentru economia țării şi pentru potențialul ei de dezvoltare, noile infrastructuri de transport trebuie să fie sustenabile, să fie imune la efectele schimbările climatice.

Sistemul de transport rutier sustenabil include structurile rutiere cu durată de viață mai mare de 40 de ani, care sunt rezistente la catastrofe, fără degradări majore şi fără pierderea funcționalității, care au impact redus asupra mediului.

Evaluarea sustenabilității structurilor rutiere se poate efectua prin Metoda Life Cycle Assessment (LCA) şi Metoda Life Cycle Cost Analysis (LCCA).

Proiectarea structurilor rutiere flexibile după criteriul sustenabilității este analizată pe baza rezultatelor obținute prin metoda Normativul PD 177-2001, folosită în România, şi două metode frecvent folosite la nivel mondial (Metoda Long Lasting Flexible Pavements, Metoda Asphalt Institute Pavements).