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Letter from the editor

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With this second annual issue of ***Transportation Infrastructure Engineering****, hosted by the electronic edition of the* ***Intersection Journal,*** *our editorial team is continuing to feature articles of innovative and timely research and development activities in all modes of transportation infrastructure. Before entering into the presentation of this number, from behalf of our editorial team, I'd like to express our thanks to the distinguished professionals, who accepted to be present in our Journal with their significant contributions in the challenging field of transportation research.*

*After an usual introductive paper: "****Transportation research and education in the new millennium",*** *intending to present a comprehensive view and synthesis of transportation research and education, as it exists today and can expect to evolve with the beginning of this new millennium, this issue is opening with a critical and comprehensive view of the actual pour technical condition of Romanian public road network infrastructure viewed in the concept of durable development. In his significant paper-document:* ***"The Romanian Road Infrastructure in the Concept of Durable Development****, the distinguished author and highway specialist* ***Neculai Tautu****, the former Director of the Regional Highway Department of Iassy and the actual President of the Moldavian Branch of the Romanian Professional Association for Roads and Bridges is proposing a challenging strategy for the preservation and development of the actual pour national road infrastructure, considered in the context of durable development. At this crucial moment, when our country concentrates its efforts to enter into the European Union, the main objectives of the strategy adopted for the modernization of the road infrastructure has to be undertaken in such a challenging way, in order to meet the requirements adopted by all European countries.*

*In his paper "****Considerations on the Value of Modulus of Subgrade Reaction", "The Average Thickness of Bituminous Binder-Criterion for analysis of Performance Behavior of Hot Rolled Road asphalt Pavements****" Consultant Professor* ***Horia Gh. Zarojanu*** *and his research team from Technical University "Gh. Asachi" of Iasi, is opening new horizons in the field of structural design and performance behaviour of asphalt pavements. His first paper is proposing specific design values for the modulus of subgrade reaction, based on a comprehensive synthesis of the existing correlations between the K value and other deformability characteristics of the subgrade such as CBR value and dynamic elastic modulus E. Specific design values for the modulus subgrade reaction are recommended to be*

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used in the frame of the actual method for structural design of rigid pavements, in our country. In his second paper the average thickness of bituminous binder is recommended as a sound criterion for the analysis of performance of hot rolled asphalt pavements.

In the series of research dedicated to various asphalt issues Professor ***Nicolae Vladimir Vlad*** *and his collaborators from Technical University "Gh. Asachi" of Iassy, presents the paper: "****The Use of Accelerated Circular Track, for Performance Evaluation and Validation of Technical Specifications for the Asphalt Mixes Stabilized with Fibers, in Romania"****, describing the research results obtained on the performance of five types of mixes, subjected to intensive accelerating testing, on the accelerated testing facility ALT-LIRA from our University.*

*In parallel with the above mentioned research, mixed road pavement structures are considered in the paper: "****The Use of Fly Ash and Volcanic Tuff for the Construction of the Mixed Road Pavements"*** *where Professor* ***Vasile BOBOC*** *and his research team are presenting their research results obtained on experimental sectors equipped with such mixed pavement structures, investigated on the same ALT facility.*

This issue is ending by a short presentation of the newly established Research Centre for Geotechnics, foundations and Modern Transportation Infrastructure Engineering "Dimitrie Athanasiu" –CCGEOFIMIT, recognized, at national level by our Ministry of Education and Research/ CNCSIS, its Mission Statement, its actual and perspective research objectives.

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Transportation research and education in the new millennium

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Summary

This paper intends to present a comprehensive view of transportation research and education, as it exists today and can expects to evolve with the beginning of this new century, based on a various published papers by internationally recognized experts fully engaged in the progress of transportation engineering.

KEYWORDS: transportation, research, education, environment, intelligent transportation systems.

1. INTRODUCTION

To mark the beginning of this new millennium, the various transportation bodies and committees from the world (TRB,[1] ERC[2], AARB[3], etc.) mounted a special effort to capture the current state of the art and practice and their perspectives on future directions in their respective areas of focus. The results of that effort was a thoughtful and perceptive review, prepared by experts fully engaged in advancing the way the traveling public is served, providing a comprehensive view of transportation as it exists today and can be expected to evolve in this new century. Various published papers [1],[2],[3],[4],[5],[6],[7],[8] present very useful information in gaining a better understanding of the current technologies, practices, and issues of interest to transportation professionals today, encouraging their readers to become major players as the new challenges are addressed by the transportation community. In this context all over the world, the quality of education in general and transportation education in particular, continue to be a major factor in a nation's ability to succeed and excel.

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[1] TRB-Transport Research Board (USA)
[2] ERC-European Road Conference
[3] ARRB- Australian Road Research Board

2. TRANSPORTATION ENGINEERING AND EDUCATION

Undertaking a short insight into the current status of transportation education as an academic discipline and examining some significant areas that may challenge educators and administrators into the near future it was found out [1], that several recommendations to support future development in this academic area are necessary to be made.

Formal education programs and academic research efforts have not always been a determining factor in the development of transportation innovations. Nineteenth century innovations, such as steamboats and railroads, initially came from entrepreneurs' talents. In the 20th century, transportation issues became more complex. In the 1950s and 1960s, education endeavors in transportation were focused on the practical matters of building and maintaining road and rail networks. In the latter part of the 20th century, transportation education became a discipline in its own right. Development in the field now comes about because of continuing demands and commitments at several levels.

For the particular case of our country, from legislative point of view, it is necessary, at this stage to issue at the level of the Ministry of Education and Research (MEC) a document, through which government could support and encourage the development of all transportation organizations (government, private, etc.) and to mandate the existing university transportation centers, Bucharest, Timisoara Cluj and Iasi, to provide leadership in transportation education teaching and research. In this respect the government has to provide appropriate research programs and the necessary funding to achieve the commitment for teaching and research, as well as a technology transfer network to link transportation education needs. The outcome benefits of such undertaking will be not only for academics, but also for practitioners at various levels who wish to learn new skills or enhance their current knowledge base. In the new economical environment, it is also expected that beside the government sector, the private sector will provide also some education commitment, based on a research component capable to meet the specific needs of a developing product/service or to transform an existing transportation enterprise.

As the transportation education system grows, the focus is changing in several ways. From an academic standpoint, additional policy areas—as opposed to technical areas—become apparent. For example, students and professors will have to broaden their scope to examine communication between public and private interests, strategic management of human and capital resources, environmental impacts, as well as the impacts of computerization and technology. In this respect, more efficient management of existing infrastructure systems are envisaged now and this can be accomplished only through the use of enhanced management systems and intelligent transportation systems. At the same time, there is a growing

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realization that transportation education needs to broaden its focus beyond academic offerings. To create future leaders in transportation careers, in the frame of the actual restructuring process, academic, elementary and secondary curricula have to be developed accordingly and revised. Some technology and transportation futures programs, capable to support lifelong learning endeavors and innovation at the elementary, secondary, college, and graduate levels have to be initiated.

At the other end of the learning spectrum, existing professionals, they themselves have to be engaging, in a lifelong learning process. Learning might also involve those who are informally interested in transportation issues. This perspective highlights the changing and evolving focus of the "transportation professional.", because in order to meet the society's demands it is no longer sufficient to have only a technical background or to view transportation education not just as a series of college courses but as a multidisciplinary and lifelong endeavor.

According this perception and in accordance with other specialist views, in this new century, some factors such as globalization, the progress of technology, changing demographics, and curriculum development will have a great impact on the educational process. In the frame of the actual globalization, defined as "seeing the whole world as nation less or borderless", in the private-sector transportation organizations provide products, services, and research capabilities to a diverse world community that is becoming more competitive. In public-sector transportation endeavors, governments at various levels are responsible for the development, implementation, and maintenance of existing and evolving transportation infrastructures. In this context, transportation education may act as the catalyst to bind these forces together by supporting innovation. Globalization and the future entrance of our country into the European Community will significantly affect the changing academic environment. In a direct sense, it will have to face and to support the internationalization of resources, not only in the individual classroom, but also in the research facility that then extends out to the workplace environment. As global transportation education efforts support industrialization, the movement of goods and people, enhanced resources, better communication, and improvements in the quality of life for all countries, outcome shares learning innovations and the latest research and development endeavors that go beyond the academic setting. These globalization forces are also enhancing a very strong competition— thus providing a wonderful opportunity for education stakeholders to show leadership through innovative research projects, as well as by utilizing technology and communication to share resources and knowledge. Transportation innovations are expected to act as an "engine of growth" among the economic and environment drivers of the actual technology revolution involving major effects on transportation education. Within the teaching environment, the use of computers as a learning tool is revolutionizing how students study existing theoretical and practical problems. Within the learning environment, research

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methodologies and outcomes are bringing about continuing change, not only in tabulating and evaluating complex quantitative problems, but also in how information is shared through web-site addresses and communication links. This revolution will extend beyond the formal classroom since it opens up distance learning opportunities to the academic and to the practitioner, even in remote locations. Technology will be used as information and learning tool to interest young students and those who wish to know more about the field. By combining technology and education endeavors, an opportunity is provided to build new technology, improve existing infrastructure, develop world-class facilities, enhance capital investments, create alternative energy sources, improve the environment, and make better communication alternatives.

At the same time, it can be used to create, test, implement, and monitor potential innovations before a financial, environmental, political, or research commitment is made. For transportation education to be relevant to society's needs, it must take into account the changing demographics in the workplace. For example, the traditional scope of jobs and careers is broadening to include women in key managerial and leadership positions, education being a key component in preparing and sustaining all individuals throughout their careers within the transportation hierarchy. To ensure broader interest and understanding for everyone, advantage should be taken of opportunities to extend the transportation learning process to the secondary and elementary levels.

At the other end of the spectrum, the older, established practitioners in the field will need to maintain and upgrade their existing knowledge and skills in the face of the massive technological and policy changes going on around them. As leaders in transportation they will have to prepare their students in such a way, that finally these students to be able to compete and demonstrate (a) leadership, to have (b) technical knowledge and skills, (c) analytical ability, (d) communication and intercultural skills, (e) technology/computerization skills, and (f) a variety of policy skills. At the same time, they need nontraditional skills, such as (g) ability to communicate between public and private interests, (h) talent to manage human and capital resources, and (i) ability to discern effects on the environment. All these objectives could be accomplished only if educators and administrators will succeed to meet changing demands through the courses of study that they offer and the research opportunities that their institutions provide. There must be a continuing commitment to broaden the focus beyond "traditional learning" to "students" of all ages. Also, there must be a commitment by numerous stakeholders to supply the tangible resources needed (e.g., funding, scholarships, grants, research opportunities, internships). Finally, educators must bridge the gap between the academic, the public, and the private sectors (e.g., by building public-private partnerships) and in a world of highly competitive resources, they need to market

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their success to academics and non-academics to build interest and support for their programs.

This complex approach is expected to have many benefits, by developing the next generation of transportation leadership and at the same time, building the field of transportation education and creates the necessary innovation to meet known and unforeseen challenges. Finally, it will contribute significantly to the developing of a safe, efficient transportation system capable to meet not only.

3. TRANSPORTATION RESEARCH. CURRENT PRACTICE AND TRENDS

There has long been widespread recognition that transportation is the foundation of e our society's economy and quality of life. The last century has brought major changes in the way we plan, coordinate, and conduct transportation research, primarily as a result of numerous trends in the transportation sector and in society as a whole. More recently, however, transportation agencies have begun to see their role as much more than simply providing infrastructure, their actual mission statements typically include enabling the movement of people and goods in an efficient, convenient, safe, and environmentally sustainable manner. In their new roles, transportation providers must interact and compete with other government departments and agencies, becoming more focused on making sound investments in transportation solutions that address strategic issues and needs.

This change requires an increased emphasis on the careful allocation of funds to achieve the maximum benefits and outcomes of the research programs, transportation research being expanded beyond traditional infrastructure concerns by including new areas such as policy, economics, sustainability, and the environment. Consequently, transportation engineers have to broaden their knowledge bases so that they will become prepared to deal with these new areas of concern and as program and project managers, to be effective at planning and delivering their products and meeting their customers' needs. Thus, in the field of road transportation, responding to an aging highway network the agencies is shifting their emphasis from building new roads to maintaining existing systems and optimizing their capacity. In addition, the construction, maintenance, and operation of transportation facilities, which traditionally was provided by government entities, are increasingly being delivered by private-sector firms and public-private partnerships.

The world's trading patterns and economies also have changed, and as communication networks continue to expand, additional change is inevitable. As economies expand from national systems to continental and global systems, new transportation issues and problems evolve in response and thus new research issues

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are emerging, challenging our professional ability to look beyond traditional borders for information, best practices, and potential partnerships. In this new environment, we must continue to imagine and to operate intermodal transportation systems that are efficient, safe, and environmentally sustainable. In this respect the envisaged research programs must demonstrate how they will support these goals while remaining responsive to the transportation profession's current and future needs. It is this balance between supporting current programs and trends and anticipating the future that allows research programs to best serve their customers, even in times of shrinking budgets.

The recent advances in the fields of communication and information technology have had major impacts on research methods. Today, we have fast and convenient access to vast quantities of information. Electronic communication technologies have made the information available to transportation researchers, making the global knowledge more readily accessible. Improved communication tools and information resources, together with stronger partnerships with marketing and communications professionals, have contributed greatly to our ability to disseminate and implement the results of our research, these factors contributing to significant and benefic trends and changes in the conduct of transportation research such as financing and administration of transportation, information management, and implementation of research results.

Thus, to secure adequate research funding, transportation research organizations must closely reflect and support the strategic goals of society, most government transportation agencies now moving away from their old mission of solely providing and maintaining infrastructure, toward facilitating and enabling a broad range of integrated services, their research departments playing an important role in helping to achieve these new institutional objectives. Research programs with a strong policy and economic component will more likely be supported by their parent organizations, because they offer the resources and expertise that senior management needs to make wise strategic investment decisions, the research managers in transportation agencies being very often regarded as part of the strategic management process. It is envisaged that, in the context of global changes and increased demand for better use of limited resources, the research organizations that excel in the future will be those that pool their resources to work on common issues and problems. Transportation organizations must find new and innovative ways to finance their research. Cooperative partnerships are an important strategy for both maximizing the value of the research investment and reducing the duplication of effort. Cooperative research programs in the United States, in Europe and around the world are strongly supported, and all partners have a solid understanding of the value and benefits that result from sharing resources .Research collaboration, in various forms, has achieved a high level of prominence and partnerships between public, private, and academic institutions are

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common and are being used more frequently to leverage available funding for best results. The recently concluded Strategic Highway Research Program (SHRP) in US and the ongoing SHRP and RO-LTPP implementation programs are excellent examples of successful partnerships among governments, industry, and academia. In Europe, by pooling funds and expertise, through various COST[4] and SERP[5] programs, and through various research bodies such as FEHRL[6], ECREDI[7], etc, the EC states are able to leverage their resources to study and develop solutions for a targeted list of problems over short (5-year) timeframes. In the foreseeable future, these arrangements will become even more common and will more often include multinational public and private sector partners. At the international level, the OCDE[8] administers research programs using pooled voluntary resources contributed by the member countries.

To justify their programs, today's research managers must be able to measure and discuss the performance, quality, and value of their programs in terms that support the strategic goals of senior management. A significant example in this respect is the ongoing COST Action 345 "Performance Based Indicators for Road Pavements", in which Romanian specialists are involved together with highway specialists from other ten European countries. Performance measures for research and development programs are currently a high priority among highway agencies. It is not enough to simply evaluate a program's performance, quality, and value. To develop and sustain support for a strong research program, researchers must proactively promote the value of research both within and outside the agency, by developing and perfecting their skills in marketing their programs and services. Today, transportation researchers also have better tools and training to carry out their work than their predecessors did. As the primary role of transportation agencies shifts from delivery of infrastructure to management of transportation services, research administrators need a broader set of management skills. Sustaining and improving the skills of the current research community and lying the groundwork for the next generation of highly trained and competent transportation researchers is a critical issue. Much work has been done to develop manuals, and courses that provide guidance and assistance in conducting research. The conduct of research will be treated in an even more systematic fashion in the future, and the emphasis on the application of superior research practices, scientific methods, networking, partnering, and marketing will likely increase.

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[4] COST-Cooperation Scientifique et Technique
[5] SERP-Strategic European Research Program
[6] FEHRL -Forum of European Highway Research Laboratories
[7] ECREDI-European .....
[8] OECD- Organization for Economic Cooperation and Development

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Because organizations with sound fiscal management practices do not spend time or money duplicating research that has already been conducted and verified, comprehensive information on the state of the art and practice must be readily available. Information based on published reports and journals, research in progress, and human expertise can be found and retrieved by using a wide variety of manuals and electronic sources, which include bibliographic and statistical databases, library catalogs, and web sites. The value of information and information services is gaining recognition among transportation researchers.

A recent study by FHWA[9] found that the money spent on information services can yield benefit-to-cost ratios in excess of 10:1 The value of information can be measured in terms of reduced costs of agency research, technology development, and operations, quicker implementation of innovations, time savings, and more effective decision making at all levels of the agency. Transportation professionals from all aver the world are becoming more aware of major transportation research resources such as the Transportation Research Information Service (TRIS) and the International Road Research Documentation (IRRD) database, as well as less focused sources. These resources provide access to the global network of research information and hence improve the quality of research and make more efficient use of resources. As the amount of information proliferates, the importance of the role of the information professional has become better understood and more prominent. Research librarians and information specialists—trained and skilled in the integration, analysis, and management of information—now are recognized as important members of the research team. Information professionals will play an important role in the organization and retrieval of web-based information systems in the future. Other information management initiatives have sprung up in recent years. For example, information clearinghouses are being developed that compile, organize, and disseminate information on high-priority topics such as those of intelligent transportation systems, work zone safety, and transportation demand management.

Concern for the timely reporting of current research is of growing interest. Information databases are only as useful as the information they contain, and research organizations are increasingly motivated to report new projects as they begin. New technologies are being developed and used to facilitate information gathering, making it easier for researchers to contribute information about their work to major international databases. So, information technology will continue to advance rapidly and significantly affect the way we exchange information, acquire new knowledge, and conduct transportation research. Issues involving the organization, storage, and retrieval of information present some of the greatest challenges that need to be addressed in the coming years. The preservation and

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[9] FHWA- Federal Highway Administration , USA

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archiving of printed transportation research documents (to ensure that documents are not lost as a result of age or deterioration) is another important concern. Finally, serious efforts must be taken to analyze and organize the volume of information being made available through web-based Internet sites, through either better design or integration of the sites as they are developed, or improved sophistication of tools that enable users to search for information across multiple web-sites.

The benefits of applied research will be realized only after the research products are implemented in the field. The information and communication tools described earlier can be used to help market innovative technologies and strategies for improving our transportation system. However, having the ability to quickly and efficiently access information about the latest research will not guarantee that the research products will be put into practice. Many barriers to the implementation of research results—resistance to change; the complexity of effective communications; and the cost and inconvenience of personal contact, which often is the most effective way to disseminate information about and learn to adopt new technologies—remain to be demolished.

The concepts behind technology transfer and its practice have received considerable attention from the transportation community during the past decade. Technology transfer generally refers to a strategy or process for bringing appropriate practices or technologies to the attention of the transportation practitioners who can benefit from them. Technology transfer has been described as a process that links research and implementation; however, it is more accurately described as an effective communication process that links information with the people who can benefit from it. Technology transfer involves packaging and communicating information in a manner most appropriate for its target audience. Technology transfer has a tremendous potential to optimize the operation of transportation systems cost-effectively, by reducing or eliminating duplicated effort and by facilitating the implementation of best practices and relevant technologies. Technology transfer in transportation will continue to expand, and the most effective practices for technology transfer will become more widely disseminated. Transportation agencies, seeking ways to hasten the implementation of research results, are increasingly encouraging or requiring researchers to develop implementation plans as part of the research process.

3. CONCLUSIONS

In the future, we probably will see even stronger ties between the research and implementation phases of innovation processes.

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Romanian Road Infrastructure in the Frame of Sustainable Development Concept

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Summary

This article presents a brief but realistic evaluation of the present situation of the road infrastructure in Romania, in order to encourage the exchange of ideas about sustainable development in this important social and economical field. It presents the present technical state of the Romanian roads, the future requirements and the available resources to bring the road network at European standards.

KEYWORDS: road infrastructure, management system, transportation costs and resources, roads technical state.

1. INTRODUCTION

The Romanian road infrastructure constitutes a significant national asset, for which important human and financial resources are devoted. In the context of severe climatic and traffic conditions, specific to our country, a complex managerial strategy applied at national, regional and local levels is necessary to be conceived and implemented in order to preserve, modernize and extend the existing public road network .

Often, the absence of a correct strategy is justified by the permanent lack of funds and financial constraints, but in our opinion this is mainly caused by the lack of proper harmonization and adaptation of the general managerial principles to the specific social- economic development level attained by the respective countries.

At this crucial moment, when our country concentrates its efforts to enter into the European Union, and when the adhesion programs have to be developed in the context of the concept of sustainable development, the main objectives of the strategy adopted for the modernization of the road infrastructure have to be undertaken in a similar concept and to meet the European Commission requirements, proposed during 2001 year.

The following base principles involved in the sustainable development and specified by Clause 130 of the Maastricht Treaty has to be considered at the establishment of the programs of road works:

- the prevention against the serious and irreversible threats toward the environment;
- consideration of the environmental problems in defining and implementation of road policy;
- the participative principle , with the implication of the society in the process of taking major decisions;
- the obligation for the polluter agent to pay for the damages he is generating.

For our country, the implementation of this concept is rather complicated, considering the service level provided by the road infrastructure and its implications on the overall costs of the transportations system, taken as a whole.

2. COSTS IN TRANSPORTATION SYSTEM

The technical state of the road infrastructure can influence decisively the transportation costs. The specialized literature in this field stresses the correlation that exists between the infrastructure and the superstructure of the transportation system, represented in Figure 1. The percentages represent mean values, which may vary, depending on the country or region. A reduction of the transportation costs with only 5% may lead to double available funds for roads maintenance and, thereafter, a continuous reduction of the superstructure costs.

According to Japanese specialists (2), one less dollar in maintenance funds today is three more dollars in transportation costs tomorrow. Considering the presented structure of the costs, one can draw the conclusion that the necessary resources must be supplied by the user (the user is paying). This problem is complex and it is not the purpose of this article to analyze the worldwide used methods in this matter.

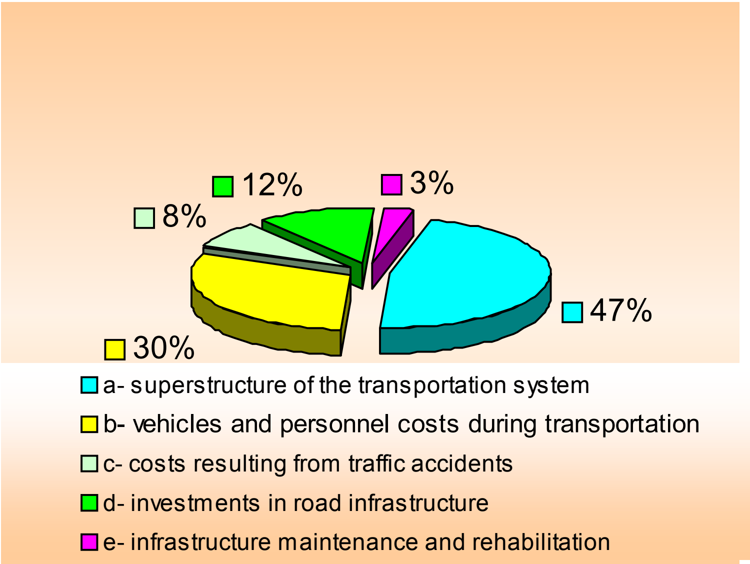

Figure 1: The structure of the costs in the transportation system

In the USA, a clearly defined principle governs the budgets of the all services (the road infrastructure representing also a service): there are no planned expenses without financing resources and also no taxes without a clear destination. In many other countries, there are cases when the money obtained from road infrastructure taxes are used in purposes other than road infrastructure works.

A very important study was done by C.E.S.T.R.I.N., analyzing the structure of taxes and tariffs applied to finance the road infrastructure works and it should be used as a strategic element for the roads management policy in our country (3).

3. TECHNICAL STATE OF THE PUBLIC ROADS IN ROMANIA

The public roads network in Romania, classified in national, departmental and rural roads, has a total length of 78658 km, according to Table 1. The evaluation of the technical state of this road network using a modern approach is practically impossible in our country At least for the departmental and rural roads, measuring some technical parameters such as surface distress, irregularities, roughness can not be evaluated observing the current standards.

Table 1. Technical condition of roads and bridges – 31.12.2004

Components			Road category			
			National	County	Local	TOTAL
0			1	2	3	4
Wearing course type [km]	Bituminous	G	7318	5226	1015	13559
		S	3157	4522	1837	9516
		B	2944	6799	1456	11199
	PC cement	G	707	515	172	1394
		S	390	318	90	798
		B	646	443	102	1191
	Gravelly		269	15985	16064	32318
	Earth		35	1602	7045	8682
Total length (km) for road category			15467	35410	27781	78658
Bridges–number of bridges/length[m]		G	1441/47995	2594/49237	779/13772	4814/111004
		S	1330/35757	1172/18755	568/9220	3070/62832
		B	384/27729	701/5720	506/6362	1591/39811

Therefore, from the data existing in each administrative department, it results the following:

For the national roads, from a total of 15166 km paved roads, 8025 km are in a good state, 3547 km are in a satisfying state and 3590 km in unsatisfying state. Also, there still are 269 km stone roads and 35 km earth roads. It must be stressed that, in between 1995 – 2004, on the national road network, an extensive rehabilitation program has been applied. It was developed in four stages and it continues now with works on E – class roads and main roads. The total length of roads in service by the end of 2004 was 2490 km, with a total value of the works undertaken of 1494790000 € (see Table 6).

For the local roads:

- departmental roads: their total length is of 35410 km, of which 5741 km are in good service conditions, 4840 km – satisfying and 7242 – unsatisfying service conditions. The length of the stone roads is 15985 km, and 1602 km are still earth roads.
- rural roads: the total length is 27781 km, of which 1187 km are in good service conditions, 1927 km – satisfying and 1558 – unsatisfying service conditions. The length of the stone roads is 16064 km, and 7045 km are earth roads.

For the national roads, but especially for the local roads, the situation is rather difficult because, in time, intervention actions were not performed regularly, which

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led to the fact that most roads have exceeded their service life, with the only exception of the rehabilitated roads.

The situation is even worse if we consider the predicted evolution of the traffic in the future. In Figure 2, presenting the traffic values for each category of public roads, it can be seen that, at the level of the reference year 2012, on the national roads the traffic is double compared to the year 2000, on departmental roads the increase is 60%, and on rural roads the traffic increase is 50%, this data being the maximal, optimistic ones.

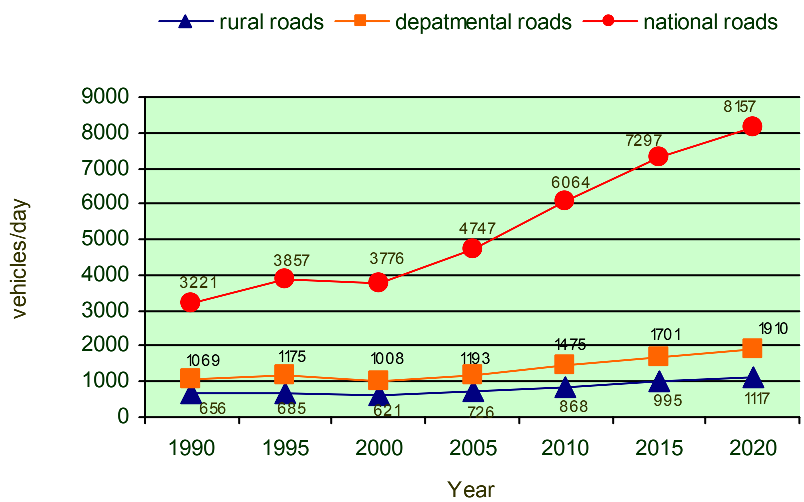

Figure 2: Traffic evolution on public roads, 1990 – 2000

4. ACTUAL RHYTHM OF IMPROVING ROAD NETWORK VIABILITY

If we consider the length of the public roads network, with various types of pavement systems – 37658 km – in between 2001 and 2004 there should have been carried out, according to the present technical norms prescribing the rhythm of interventions, maintenance and rehabilitation works on 12552 km, which means an intervention every 12 years. However, in Table 2 it can be seen that the total length on which such works have been carried out is 4864 km.

Table 2. Road works carried out during the period 2001 – 2004

Type of works	Road category length [km]				
		National	Country	Local	TOTAL
0	1	2	3	4	5
Structural overlay	number	1797	373	116	2287
	value	327958428	19963139	6456886	354378453
Reconstruction	number	186	1534	61	1781
	value	17242103	72013053	3686096	92941253
Surface asphalt treatments	number	2885	3862	110	6857
	value	21132425	26466985	2143754	49743164
Thin overlay (I.A.U.)	number	17	679	470	1166
	value	1554021	39872661	46016373	87443055
Gravelly	number	0	1172	2175	3347
	value	0	6660819	112946025	119606844
Recycling	number	535	84	0	619
	value	57421004	4112663	0	61533667
Total value [euro]		425307981	169089320	171249134	765646436

The situation, for each road category, is as fallows:

- national roads: total length: 15163 km; works done on 2473 km;
- departmental roads: total length: 17823 km; works done on 1906 km;
- rural roads: total length: 4200 km; works done on 176 km.

Concerning the bituminous surface treatments, the situation is also difficult. According to the standards, every 5 to 7 years, any flexible pavement must be rejuvenated. This means that, in four years, at least 75% (28244 km).

Globally, only 6875 km roads were treated: 2885 km national roads, 3862 departmental roads and 110 km rural roads. A better situation exists in the case of stone paving earth roads, but still insufficient: 3347 km done, from 11000 km existing earth roads in 2001. The total value of the funds used in 2001 – 2004, presented in Tables 3 and 6, is 1.627.687.721 €, from which 269.500.000 € were for rehabilitation works.

5. GLOBAL REQUIREMENTS FOR PUBLIC ROADS NETWORK FOR SATISFYING ECONOMICAL AND SOCIAL NEEDS

For determining these requirements, the delays of the maintenance programs have been taken into account, as well as the objective of bringing the roads and bridges network to satisfying service levels.

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The structure of the costs involved is presented in Table 3.

Table 3. Road works budgeting during the period 2001 – 2004

Budget by source [euro]	Structure of the costs						
	Administration	Investments		Capital repairs		Current and periodical maintenance	TOTAL
		Roads	Bridges	Roads	Bridges		
0	1	2	3	4	5	6	7
Budget by source [euro]	8447268	19320062	5182773	8409706	1861085	380615479	423836374
Local budget	5419623	14025583	8665781	5939858	1583586	128581377	164215808
Own income	19067188	0	26796	0	0	87878968	106972952
Credits	4297522	3717787	154983	1358870	75421	111078799	120683381
Special fund	2503911	69510026	33046933	33300439	17621618	270759799	426742725
Other sources	850149	65816521	8954049	6328145	538469	33249146	115736480
Total value [euro]	40585662	172389981	56031318	55337022	21680184	1012163574	1358187727

The rehabilitation works for national roads have been estimated according to the strategy of the rehabilitation campaign, stating that at the end of this program (2012) the length of the European and main roads should be 6000km. For treatment works, the tasks were estimated according to the maintenance technical norms.

From Table 4, it results that the global cost is 10.407.830.689€: 4.343.565.324€ for national roads, 3.708.804.001€ for departmental roads and 2.355.465.364€ for rural roads.

Concerning the budget needed for bridges, the situation is presented in Table 5. The works considered were replacing provisory bridges, rehabilitation and maintenance. The total evaluated cost is 1.249.419.824 €. The global cost for finalizing this program is 11.657.250.513€.

6. AVAILABLE RESOURCES

After globally evaluating the required budget for improving the technical state of the road network, for the national, departmental and rural roads only, without considering the highways and village roads, an inventory of the possible resources to cover these needs is done (Figure 6.1, Figure 6.2).

Table 4. Funds necessary for roads, for the period 2006-2012

Type of works	Road category							
	National		County		Local		TOTAL	
	number	value[euro]	number	value[euro]	number	value[euro]	number	value[euro]
0	1	2	3	4	5	6	7	8
Administration	-	131962013	-	321186647	-	141286774	-	594435434
Rehabilitation	3400	1428187000	-	-	-	-	3400	1428187000
Structural overlay	3229	919353136	7090	1134400000	1672	267520000	11991	2321273136
Modernization	483	167376048	4157	760731000	2116	387052370	6756	1315159418
Thin overlay (I.A.U.)	144	18000000	3357	453195000	3920	529200000	7421	1000395000
Gravelly	0	0	2206	173985000	8605	678667740	10811	852652740
Maintenance total	-	1678683127	-	865306354	-	351738480		2895727961
From which, surface asphalt treatments	13850	179898014	5761	110900595	1997	28189586	21608	318988195
Total	-	4343561324	-	3708804001	-	2355465364	-	10407830689

Table 5. Funds necessary for viaducts and bridges, for the period 2006-2012

Road category	Necessary works							
	Finishing already started works		Capital repairs		Maintenance		Total value	
	pieces/ length [m]	value [euro]	pieces/ length [m]	value [euro]	pieces/ length [m]	value [euro]	pieces/ length [m]	value [euro]
0	1	2	3	4	5	6	7	8
National	171	422960339	939	248853365	1607	229924967	2717	901738671
	6104		43463		55125		104692	
County	125	37542769	653	154785427	2160	74726274	2938	267054470
	2656		8609		35523		46788	
Local	65	15100745	385	45441413	573	20084525	1023	80626683
	896		1991		5809		8696	
TOTAL	361	475603853	1977	449080205	4340	324735766	6678	1249419824
	9656		54063		96457		160176	

6.1. Transfers government budget – this resource has been used continuously and many times exclusively. It could never withstand the real needs, being insufficient for the whole network, but especially for local roads.

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6.2. Taxes and tariffs – this must be paid by those who use the road network, directly or indirectly. This resource is broadly used abroad, with various modalities of collecting and managing the funds. For our country, the system, only partially used now, must be reconsidered and adjusted to observe the European standards.

Table 6.1. National roads rehabilitation with external and internal resources

Stage	Length [km]	Value(including VAT) [thousands euro]	Completed %
I	1031	334310	100
II	714	406175	100
III	412	323610	84
III	bridges	13849	100
IV	315	225456	40
TOTAL	2472	1303400	92

Table 6.2. National roads rehabilitation with ISPA and PHARE funds

Stage	Length [km]	Value(including VAT) [thousands euro]	Completed %
III	182	80858	75
III	bridges	9626	100
IV	109	85271	50
V	35	15635	3
TOTAL	326	191390	67

According to the norms of the European Union concerning taxes for roads users, the value of these taxes must reflect the wearing of the pavement due to the axle loads, the distance, the pollution due to carbon dioxide (CO2) emissions. In this matter, The European Commission has published The White Book, referring to the taxes for using the road infrastructure.

The taxes and tariffs types, some of the also used in our country, are:

- taxes included in the price of the fuel, in most countries used for road maintenance works. Unfortunately, the management of these funds is done by the Ministry of Finance, which sometimes leads to the situation presented in Figure 3, where funds for roads works are allocated arbitrarily.
- transportation authorizations;
- custom taxes and excises for motorized vehicles imports;
- taxes and tariffs for transportation authorizations for high tonnage and special transportations ;

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- taxes and tariffs for alien transporters, replaced more and more by transportation authorizations released on reciprocity bases.

Normally, the funds obtained from all these taxes, as well as others, such as those obtained from envelopes or vehicles selling, should be used for financing roads works.

The taxes for roads infrastructure from fuel purchase varies in every country, being in the range of 25% to 50% from the total price. Usually, these taxes decrease as the number of registered motorized vehicles increases.

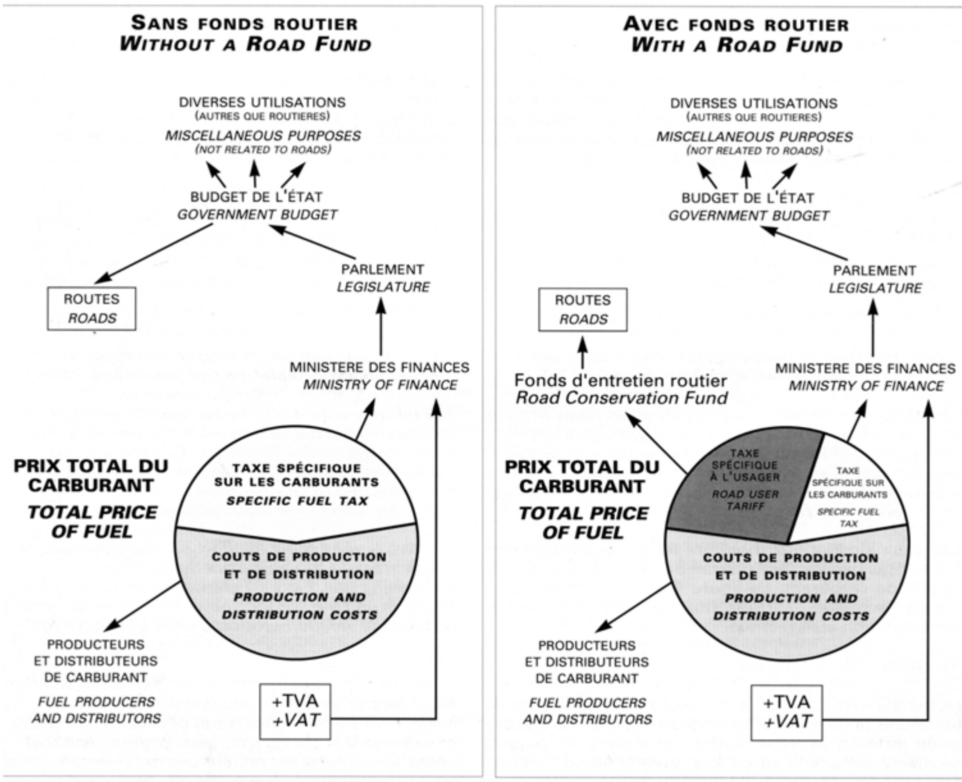

Figure 3: Use of money paid for the purchase of fuel

6.3. A very important resource can be considered the savings due to good timing interventions for preventing the degradation of the road. This could dramatically decrease the maintenance costs, witch increases exponentially with the delay of the intervention works. An example is the decision of withdrawing the technical agreement for bituminous treatments and recycling.

For Romania's situation, if a strategy to realize the objectives (7 years) is found, so that the repairing works amount is reduced every year, the saved funds could

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constitute real resources to cover the payments and the interest rates for the credits used in the program.

6.4. The volume of the works done by the Road Agency compared to those executed based on contracts also represents an important resource. In countries such as Sweden, Finland, Great Britain, important savings have been obtained by executing the current maintenance and winter works.

6.5. A resource difficult to evaluate, but extremely important to manage all categories of costs affecting the road infrastructure, is the quality of the specialists in this activity field and the quality of the management.

The training and the stability of the human resources in a pavement management system is a must. At this point, there exists a shortage for highly qualified personnel. The number of future graduates in this field must be reconsidered.

6.6. Early execution of studies and projects for road infrastructure development, done and supervised only by specialists. The cases when unfounded decisions were made were more than few, leading to increased costs or inefficiency. Preparation of consistent projects is even more important in the following period, as Romania will have access to important financing resources from European Community funds.

6.7. The structure of the works program may and must influence the costs on medium and long term. The works aiming for conserving the pavement systems must have top priority. As an example, it can not be allowed that an agency executes structural overlaying, but skips the surface treatments works (6).

Although the issues presented at points 6.3 – 6.7 can not be exactly evaluated, these aspects represent certain measures for reducing the maintenance costs as well as strategic elements in the frame of the national pavement management system.

7. CONCLUSIONS

This article presents a brief but realistic evaluation of the present situation of the road infrastructure in Romania, in order to encourage the exchange of ideas about sustainable development in this important social and economical field, and it is addressed to all the decision – makers, at all levels, with various responsibilities in initiating and promoting new development strategies for the Romanian road infrastructure.

The problem presented is very important also because it involves difficulties in assuring the necessary financial support. However, accomplishing the objectives of the proposed program for 2006 – 2012 could dramatically change the image of Romania.

Generally, a document such as this article presents at the end vast conclusions and program of measures. Still, we consider that a main conclusion, and measure to be taken, is of the most importance: the Romanian road infrastructure must be managed by a National Roads Program, elaborated by the National Roads Administration on legal basis. This program will eventually define a balance of requirements and resources, as well as the responsibilities of those who will carry out the objectives and who will assure the resources.

The National Roads Program, on medium and long term, will be approved by the Parliament and actualized by Governmental Ordinance. This objective is in accordance with the present Government Program. Chapter 17 – „Transportation policy", point B – „Road infrastructure strategy".

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Considerations on the value of modulus of subgrade reaction

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Summary

In structural design practice of rigid road pavements, the subgrade stiffness is generally represented by the modulus of subgrade reaction, now universally known as subgrade support or by the symbol K (K Value). As the in situ determination of the K value is laborious, a synthesis of correlations between K value and other deformability characteristics of the subgrade such a CBR and the dynamic elastic modulus E for which standardized values are available, is presented in this paper. Based on this synthesis, design values for the modulus of subgrade reaction have been adopted and proposed for the use in the frame of the actual structural method of design of rigid road pavements, elaborated by INCERSTRANS in collaboration with the Faculty of Civil Enginering of Iasi.

KEYWORDS: rigid pavements, structural design, modulus of subgrade reaction, deformability characteristics

1. INTRODUCTION

The modulus of subgrade reaction, universally known by the symbol K, is the number of pounds per square inch of subgrade reaction per inch of slab deflection, pounds per cubic inch or kN/m^3 .Usually this parameter, characterizing the subgrade stiffness is measured in situ), by applying a static load , on a 30-in diameter bearing block (plate).

According /6/, "no time rate of load application is included in the definition for modulus subgrade reaction, but the fact is that fast moving traffic loads are less severe in their slab-bending effect than static loads" and therefore it is assumed that static loads are significant loads for this purpose. As this process is quite laborious and costly, for preliminary design stages (pre-feasibility -SPF or feasibility-SF stages)and for construction objectives of minor importance such as local roads, parking or storage surfaces, K Values , obtained on the base of the following types of correlations are recommended to be used:

$$E_{\text{elasticitate dinamic}} - CBR \qquad [\,MPa\ ;\ \%\,] \qquad (1)$$

$$K - CBR \qquad [\,MN / m^3\ ;\ \%\,] \qquad (2)$$

2. STUDIES OF VARIOUS CORRELATIONS

2.1. Studies undertaken for correlations of type (1)

For correlations of type (1) the following relations have been considered:

LCPC Paris : $E = 5(CBR)$ (3)

TRRL London: Table1

Table1. Correlations of type (1) recommended by TRL specifications

CBR [%]	1,5	2	5	15
E [MPa]	23	27	50	100

C. Regis : $E = 8{,}5\ (CBR)^{0{,}825}$ (4)

G. Jeuffroy : $E = 6{,}5\ (CB\ R)^{0{,}65}$ (5)

Shell : $E = 10{,}0(CBR)$ (6)

TEM / 1 / Table 2 :

Table 2. Correlations of type (1) recommended by TEM specifications:

CBR [%]	1,5	2	3	4	5	6	7	8
E [MPa]	14,5	20,0	26,5	32,0	37,5	42,0	46,0	50,0

For the correlations given in Table 1 and Table 2, the involved equations (Table 3) have been determined ; x = CBR ; y = E [MPa]:

Table3. The involved equations for the correlations given in Table1 & Table 2

Correlation	Equation	Coefficient of correlation	Standard deviation	Statistical residue
TRRL (table 1)	$y = \dfrac{a*b + c*x^d}{b + x^d}$	1,000	0,0	0,0
TEM	$Y = a+b*x+\ldots+f*x^5$	0,999	0,047	< 0,03

The pairs: CBR –E values for those six correlations of type (1) are presented in Table 4:

Table 4. The pairs: CBR –E values, for those six correlations of type (1)

CBR [%]	E [MPa] for the correlations: :					
	(3)	(tab.1)	(4)	(5)	(6)	(tab.2)
1,5	7,5	23,0	12,0	8,5	15,0	14,5
2	10,0	27,0	15,0	10,0	20,0	20,0
3	15,0	35,0	21,0	13,5	30,0	26,5
4	20,0	42,5	26,5	16,0	40,0	32,0
5	25,0	50,0	32,0	18,5	50,0	37,5
6	30,0	56,5	37,5	21,0	60,0	42,0
7	35,0	63,0	42,5	23,0	70,0	46,0
8	40,0	69,0	47,5	25,0	80,0	50,0

In technical specifications for the structural design of rigid pavements/5/ the Shell correlation has been retained , as this correlation ensures a resonable correlation of the design values of the dynamic elastic modulus of subgrade for flexible/semirigid road pavement structures.

2.2. Studies undertaken for correlations of type (2)

For correlations of type (2): C.T.12 AIPCR /2/, TEM /1/ and PCA /3/, the results from Table 5 have been obtained:

Table 5. Correlations of type (2)

CBR [%]		10	9	8	7	6	5	4	3
K [MN/m$^{3]}$	CT 12	60	55	52	48	42	37	33	27
	TEM	55	51	48	46	41	37	33	27
	PCA	54	52	49	45	42	38	33	27
K_{mediu}[MN/m^3]		56	53	50	46	42	37	33	27

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For K_{mediu} , the correlation (7): x= CBR; y=K, from below has been derived :

$$y = 8,74 + 6,75*x - 0,202*x^2 \tag{7}$$

this correlation having the following statistical parameters: R (the coefficient of correlation) =0,999; the standard error =0,323; statistical residue < 0,50.

The E [MPa] / CBR [%] / K [MN/m^3] values, adopted according /5/ , for the P_1 …P_5 types of subgrade soils, for the climatic types I…III and for the hydrological conditions 1…2b, are presented in Table 6:

Table 6 The adopted values of E / CBR / K, for the various types of subgrade soils

<table>
<tr><th rowspan="2">Climatic Type</th><th rowspan="2">Hidrological conditions</th><th colspan="5">The adopted values of E / CBR / K for the various types of subgrade soils</th></tr>
<tr><th>P₁</th><th>P₂</th><th>P₃</th><th>P₄</th><th>P₅</th></tr>
<tr><td rowspan="3">I</td><td>1</td><td rowspan="9">100/10/56</td><td rowspan="5">90/9/53</td><td>70/7/46</td><td rowspan="2">80/8/50</td><td>80/8/50</td></tr>
<tr><td>2a</td><td rowspan="5">65/6,5/44</td><td>75/7,5/48</td></tr>
<tr><td>2b</td><td>70/7/46</td><td>70/7/46</td></tr>
<tr><td rowspan="3">II</td><td>1</td><td rowspan="2">80/8/50</td><td>80/8/50</td></tr>
<tr><td>2a</td><td rowspan="2">70/7/46</td></tr>
<tr><td>2b</td><td>80/8/50</td><td>70/7/46</td></tr>
<tr><td rowspan="3">III</td><td>1</td><td>90/9/53</td><td rowspan="3">60/6/42</td><td>55/5,5/39</td><td>80/8/50</td></tr>
<tr><td>2a</td><td rowspan="2">80/8/50</td><td rowspan="2">50/5/37</td><td rowspan="2">65/6,5/44</td></tr>
<tr><td>2b</td></tr>
</table>

The design value of the reaction modulus K_0 , at the superior level of subgrade is obtained function of the value of the subgrade reaction modulus K and the equivalent thickness (type AASHO Road Test), by using the diagram SBA /STBA Paris /4/.

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3. CONCLUSIONS

In the frame of the Romanian method of structural design of rigid roads pavement structures/5/, the reaction subgrade modulus K [MN / m^3] represents the stiffness characteristic of the subgrade.

The correlations between the value of the reaction subgrade modulus K and the E the dynamic elastic modulus –MPa) and CBR [%], for which laboratory or standard design values are available, permit the evaluation of the design values K, at least for the preliminary design stages, thus eliminating the in situ laborious and tedious studies.

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The average thickness of bituminous binder – criterion for the analysis of performance behavior of hot rolled road asphalt pavements

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Summary

Although the average thickness of the bituminous binder does not represent a criterion for the design of the composition of the asphalt mixtures, it could be useful for the analysis of the premature distressed observed in the asphalt pavements. This paper intends to present the method of calculation of this parameter and suggests its correlation with the performance of the asphalt pavements, expressed in terms of type and extension in time of the specific distress phenomena. These correlations could be then recorded in a road data base, in order to be use, later on, for such analyses.

KEYWORDS: asphalt pavements, laboratory design, the average thickness of asphalt binder, road data base

1. INTRODUCTION

Although the average thickness of the bituminous binder does not represent a criterion for the design of the composition of the asphalt mixtures, it could be very useful for the analysis of the premature distresses observed in the asphalt pavements. If this thickness is too small, air will penetrate easier into the asphalt mix voids, thus leading to its faster oxidation, increased stiffness and cracking of the binder film.

This situation becomes more critical in case of using mineral aggregate susceptible to the action of water whose access at the surface of the aggregate will lead to the development of specific distresses.

This criterion is not applicable to the hot poured asphalt mixes, where the volume of binder exceeds the volume of voids in mineral aggregate.

2. USEFUL RELATIONS FOR THE CALCULATION OF THE AVERAGE THICKNESS OF THE BITUMINOUS BINDER

according literature /1/,/2/,/3/, the average thickness of the bituminous binder (h_{bm}) in an asphalt mix is derived from the effective volume of the bituminous binder (V_{ef}), which represents the difference between the total volume of binder (V_t) and the volume of the binder absorbed by the natural aggregate (Va), by using various usual relations.

2.1 The calculation of the average thickness of the bituminous binder

The average thickness of the bituminous binder (h_{bm}) is obtained by using the following relation:

$$h_{bm} = \frac{V_{ef}}{\sum_a M_a} \quad [m] \qquad (1)$$

where: V_{ef} represents the effective volume of the binder [m^3] :

$$V_{ef} = V_t - V_a \qquad (2)$$

Σ_a - the total surface of the mineral aggregate (m^2 / kg);

M_a – mass of mineral aggregate (kg).

2.2. The calculation of the total volume of binder:

The total volume of binder (V_t) is calculated with the relation (3):

$$V_t = \frac{M_m * p_b}{\rho_b} \quad [m^3] \qquad (3)$$

where the involved parameters have the following significance:

M_m the mass of the asphalt mix (kg);

p_b - the percentage of binder (%);

ρ_b - the density of the bituminous binder [kg / m^3].

2.3 Calculation of the volume of the absorbed binder

The volume of the absorbed binder (V_a) by the mineral aggregate is obtained by using the relation (4):

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The average thickness of bituminous binder

$$V_a = \frac{p_{ba} * M_m * (1 - p_b)}{\rho_b} \quad [m^3] \qquad (4)$$

where p_{ba} represents the percentage of the absorbed binder, determined with the relation (5) :

$$p_{ba} = 100 \frac{\rho_a - \rho_{aa}}{\rho_a * \rho_{aa}} \qquad (5)$$

In relation (5), ρ_a represents the efective density of mineral aggregate , calculated with the relation(6):

$$\rho_a = \frac{100 - p_b}{(100/\rho_m) - (p_b/\rho_b)} \quad [kg/m^3] \ , \qquad (6)$$

The parameters involved in relation(6) have the following significance :

ρ_m -represents the maximum theoretical density of the asphalt mix , e.g. of the mix without voids [kg / m^3];

ρ_{aa} - represents the apparent density of the mineral aggregate and is calculated with the relation (7) , [kg / m^3] :

$$\rho_{aa} = \frac{\sum p_{ai}}{\sum (p_{ai}/\rho_{ai})} \quad [kg/m^3] \qquad (7)$$

p_{ai} - the percentage of aggregate size "i", having the apparent density ρ_{ai}.

2.3 Calculation of thetotal surface of the mineral aggregate

For the calculation of the surface aggregate Σ_a , in relation (1), the Duriez formula or the Asphalt Institute relation (8) can be used :

$$\sum_a = \sum a_i * p_i \qquad (8)$$

where : ai represents the surface factor for the material passing the sive „ i „ in percentage „ pi"., in accordance with the values given in Table 1 from below:

Table 1. The values of the surface factor ai

Sieve	The maximum size*)	Sieve Number						
		4	8	16	30	50	100	200
Sieve size -mm-	Sieve size	4,75	2,36	1,18	0,60	0,30	0,15	0,75
Surface factor a_i	2	2	4	8	14	30	60	160

*)sieve through which 100% aggregate is passing

3. CONCLUSIONS

For the determination of the average thickness of the bituminous binder in an asphalt mix, there is no need for supplementary laboratory tests, the data obtained during the design stage of the asphalt mix are sufficient in this respect.

The determination of the average thickness of the effective film of binder and its correlation with the performance behaviour of the asphalt pavements, expressed in terms of the types of distresses and of the time of their observance , is fully justified for the creation of a specific road data bank by each Road Agency.

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The use of accelerated circular track for performance evaluation and validation of technical specifications for the asphalt mixes stabilized with various fibers, in Romania

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Summary

The research presented in this paper has been undertaken in the frame of Accelerated Load Testing (ALT -LIRA) facility at the technical University "Gh. Asachi" of Iassy, for performance evaluation and validation of national technical specifications for the asphalt mixes stabilized with various fibers, used for the construction of bituminous road pavements in the actual effort of road rehabilitation in Romania. The performance of five types of mixes involved in this research has been monitored and evaluated at various stages of the accelerated experiment before reaching the complete failure and compared between them and with the performance of a reference mix on a witness sector. Finally, specific failure criteria and valuable recommendations have been proposed for the use of practice industry, in this country.

KEYWORDS: stabilized asphalt mix, accelerated performance testing, permanent deformation, failure criteria.

1. INTRODUCTION

Since the year 1993, marking the beginning of a huge and resolute effort of National Administration of Roads, directed towards the rehabilitation the public road network, the Romanian specialists have been confronted with the difficult task of selection and implementation of new asphalt technologies, in order to replace the old and outdated ones, and to permit the design and construction of stronger and better flexible pavements. These new pavements were seek to exhibit a better performance of the existing road network, to the severe traffic and climatic conditions, characterized by the sudden increase of the traffic volume, parallel with the adoption of the axle load of 115KN, and by huge temperature gradients between the hot and cold seasons.

A first and successful step realized in the frame of this strategy, was the research and implementation in the current road rehabilitation practice of the MASF16/8

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type mixes [1], [2], stabilized with various fibers, customized to the specific technical properties if the Romanian aggregates and binders. The application of these superior mixes is now generalized on all road rehabilitation projects, in this country.

A second step was the adoption and implementation of the specific testing technology [3] for assessing the susceptibility of these mixes to rutting, in the conditions of very high temperatures reached in the asphalt pavement during the summers, for some regions, these temperatures over passing 65°C, according SHRP Algorithm [4].

A third and very important step was the undertaking of accelerated testing of these type of mixes, stabilized with indigenous or imported fibers, in order to assess and validate, in a short time, their behavior and performance under the specific new adopted axle load of 115 kN. This paper describes the approach and presents the results of a two year research study undertaken in the frame of Accelerated Load Testing (ALT) facility at the Technical University "Gh. Asachi" of Iassy, for performance evaluation and validation of technical specifications for the asphalt mixes stabilized with various fibers, used for the construction of bituminous road pavements in the frame of the ongoing effort of road rehabilitation in Romania. Five types of mix have been selected for this study. The performance of those five types of mixes involved in this research has been monitored and evaluated at various stages of this experiment, under loading on the accelerated circular track, before reaching the complete failure and compared between them and with the performance of classical reference mix, laid on a witness sector. Finally the study was completed with the laboratory investigations on cores in order to assess the evolution of the asphalt mix properties under the total of 2,2 x 10^6 passes of the standard axle load of 115 kN.

2. THE ACCELERATED TESTING FACILITY

Full scale accelerated pavement is defined [5] as "the controlled application of a prototype wheel loading ,at or above the appropriate standard (legal) load limit, to a particular structural pavement system, in order to determine the pavement response and performance under a controlled, accelerated, accumulation of damage in a compressed time period". The research facility of Technical University "Gh. Asachi" of Iassy is an experimental site, named LIRA (Laboratorul de Incercari Rutiere Accelerate) housing a full-scale accelerating circular testing track, its name and main technical parameters being described also in the related literature[6], among those 32 accelerated facilities developed all over the world after the 1962 year. In fact the first generation of this facility has been developed at the Iassy Technical University, since 1957 year, and the actual third generation is the only existing facility of this type in this country and also in the South-East European Region, now being actively involved in the EC research transport program: COST 347.[7] The accelerated road research facility from Iassy University is one of those provided a circular track dedicated to the experimentation of various road pavement structures. The main modifications brought to the initial facility along the last 45 years, consisted mainly in the increase of the loading capacity and the extension of the length of running truck [8], [9]. Thus, with the first generation facility, which was functioned during the years 1957…1983, the length of the running arm was of 10 meter, and its mass of 4.6 tone transmitted to the investigated road structure a load of 23kN by two simple wheels, placed at the ends of the metal arm, the total length of the circular track being of 31.4 meter. With the second generation, built on a new location and made functional since 1983 year, the new running installation had a total mass equal with that of the standard design vehicle: A13, and transmitted to the road structures a load of 45.5 kN by two groups of twin wheels. The length of the arm has been increased to 15 meter, so that the total length of the circular track have reached to 47.1m, thus becoming possible the simultaneous testing of many sectors with representative lengths, and with a greater number of measuring points, in order to get sufficient data for statistical interpretation. The adoption in of the new standard axle load of 115 kN, in the 1997 year, led to the development of the third generation facility [10], [11], equipped with a new arm with a sufficient mass, capable to assure this new load. The running speed during the loading was maintained at 20 Km/h, from both security and technical reasons (the applied frequency of loads 4.25^{-1} sec, is quite sufficient).

3. INSTRUMENTATION

Even the instrumentation was not at the level of other similar accelerated facilities from abroad, the quantification of the main test parameters has been achieved, in order to get significant conclusions. These parameters, the instrumentation used and their precision and other useful information are given in Table 1.

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Table 1. The main parameters investigated during the accelerated testing on the circular track

No	The investigated parameter	The instrumentation	Precision	Number of investigated points on the circumference	Position	The level from the pavement surface
1	Total deformation (wearing + permanent deformations)	The reference straightedge	0.01mm	40	Transverse profile	At the pavement surface
2	Elastic deformations (deflections)	Soiltest/ Benkelman beam or FWD	0.01mm	All	In the middle of the circulated strip	At the pavement surface
3	The radius of curvature	Device for measurement of the radius of curvature	0.01mm	All	In the middle of the circulated strip	At the pavement surface
4	The bearing capacity of the bearing structure	Loading plate	0.01mm for deformations	8	In the middle of the circulated strip	At the subgrade level and at the surface of each layer
5	The level of the underground water	Straightedge	5mm	4	At the inner circumference of the track	0.5….1.5m
6	The temperature	Thermocouple (copper/ constantan)	0.5ºC	4	Any point	0.5….1.5m
7	Soil moisture content in subgrade	Normal soil sampling/ using standard methods/ drying)	0.1%	4…10	Any point	0.5….1.5m

4. PLANNING THE EXPERIMENT

Five sectors having an identical road pavement structures, each one equipped with a wearing course having the same thickness (4 cm) but realized from a specific mix; four of them has been equipped with asphalt mixes stabilized with indigenous or imported fibers, selected from those currently used in the road rehabilitation practice and the fifth one was equipped with a classical mix (asphalt concrete type BAR16) and considered as an witness, reference sector. All five experimental sectors have been subjected to accelerate testing, on the circular track, under the repeated axle load identical with that of the standard vehicle. The adopted road pavement structure corresponded with that currently used in the ongoing road rehabilitation program, phase II, with a small reduction (20 cm instead of 23 cm) brought to the thickness of the foundation layer constructed from granular materials (ballast) stabilized with cement, as consequence of the reconsideration of the higher bearing capacity of the subgrade soil in the process of verification of the standard structural design. Finally, the following pavement structure has been adopted:

- subgrade layer (ballast): 25 cm;
- base course layer (natural aggregates stabilized with 5% cement): 20 cm;
- asphalt base course layer: 8cm;
- asphalt binder course: 4cm;
- asphalt wearing course: 4cm;

For the construction of the experimental sector on the circular track have been accepted and used only those materials proving to meet the quality conditions specified by the legal technical norms. As the objective of the research was the performance study of asphalt mixes with better resistance to the rutting phenomena induced by the heavy traffic, four types of asphalt mixes stabilized with various fibers, having compositions as shown in Table 2, have been selected.

Table 2. The asphalt mixes involved in the accelerated experiment

The component	Type of ix involved in the accelerated experiment				
	MASF 16 stabilized with imported cellulose fiber 1	MASF 16 stabilized with imported cellulose fiber 2	MASF 16 stabilized with indigenous textile fiber 3	MASF 16 stabilized with indigenous textile fiber 4	Classical asphalt concrete BAR 16
Chippings 8/16 (%)	41.8	41.9	37.5	37.5	42.5
Chippings 3/8 (%)	27.2	27.3	25.3	25.3	22.0
Quarry crashed send 03 (%)	16.1	16.2	24.4	24.4	22.8
Filler-lime stone (%)	8.3	8.4	6.6	6.6	7.6
Bitumen D60-80 (%)	6.5	6.2	6.2	6.2	5.1
Fibers (% from mix)	0.3	0.3	0.3	0.3	–

The imported (Germany) cellulose fibers used in the experiment have dimensions of the order of microns, whereas the indigenous textile fibers are obtained by whirling of individual threads, their length being of 15..30 mm and the diameter of over 1mm. Laboratory studies for establishing the mix composition has been undertaken for each type of mix, taking into consideration the provisions of the existing technical specifications (SR 174/97 for mixes and Technical Agreement for cellulose fibers), and seeking to obtain a volume of air voids in the compacted mix of around 3.5%. Thus the bitumen content considered during the study was in the range of 6.2% to 7.2% for the MASF type mixes and in the range of 5.7% to 6.2% for the BAR16 mix. The percent of fiber was 0.3% from the mass of mix. At least three alternatives of bitumen content have been studied for each type of mix , the maximum limits (7.2% for the asphalt mixes stabilized with cellulose fibers and 7.2% for the mixes stabilized with textile fibers) being established in accordance with the requirements imposed by the Schellenberg Test (maximum 0.2%) [12].

The asphalt mixes have been prepared in a DS158 installation with a productivity of 40m^3/h, the fibers being introduced directly in the mixer, the mixing time for the dry mix (aggregate + filler + fiber) being of 30 seconds, the mixing being continued after the adding of bitumen for another 30 seconds. The laying of the asphalt mix has been made manually, followed by compaction with the vibrating roller with a total mass of 1500Kg. The wearing layer, in those five alternatives has been laid accordingly, each sector having a total length of 9.5 m. The temperature

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conditions were carefully observed and recorded during al the process and the required compaction degree for each layer has been achieved. Samples taken from each mix during the laying process have been investigated in terms of composition and mechanical characteristics.

5. CONDUCTING THE EXPERIMENT

All five sectors have been subjected to the accelerated testing under the running installation having a total weight equal with that of the standard axle load (115kN), this load being transmitted to the pavement through a set of twin wheels placed at the end of the running installation. By the symmetric assembly of this installation, a circulated on strip o of 65 cm width, on which the wheels are passing two times with each complete rotation of the installation arm, with a frequency of load of 4.25 sec^{-1} for the running speed of 20Km/h. The total number of 2,2x10^{6} have been achieved during a period of 22 months (January 2000…October 2001), this period including two hot and two cold seasons, the temperature recorded in the closed space of the accelerated facility being in the range of 10°C to 15°C during the cold season and of 35°C to 37°C during the hot one.

As it was mentioned before, one of the aims of the experiment was the testing of the capacity of the investigated asphalt mixes stabilized with fibers to resist the rutting trend and in this respect the main parameter monitored during the test was the permanent deformation of the pavement, measured at various stages of loading. Thus measurement of the surface level of the wearing course has been performed, with the precision of 0.1 mm, in a number of eight transverse profiles for each sector, the distance between the measured points on the same profile being of 20mm, as shown in Fig.1.

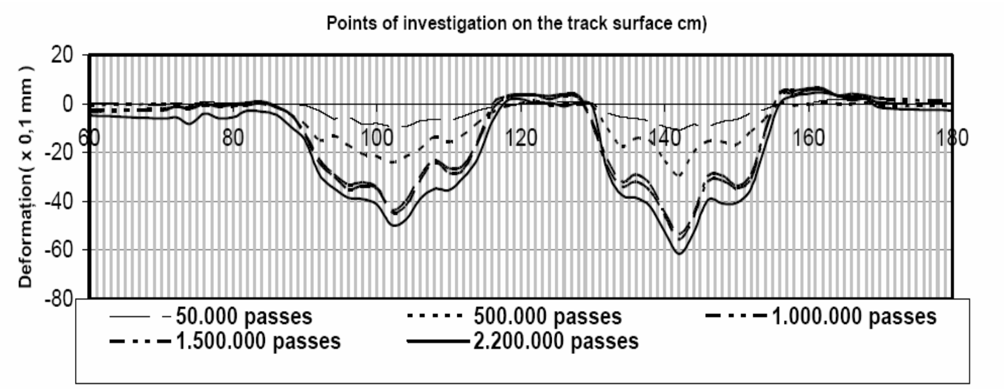

Fig. 1 Average permanent deformations - Sector 1, Asphalt mix with cellulose fiber 1

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By making the difference from the initial recording, made just before submitting the pavement to the accelerated traffic, the value of permanent deformation recorded for each stage of loading has been obtained, the measurements being performed at the following loading stages: 10,000, 100,000 passes, and then at each additional $100x10^3$ passes till the achievement of the final traffic of 2,2 $x10^6$ passes of the standard axle load of 115kN.

Fig.1 presents the permanent deformations recorded during the test for the experimental sector equipped with an wearing course realized from asphalt mix type MASF16, stabilized with cellulose fiber type 1, after five significant stages (e.g. after 50,000, 500,000, 1,000,000, 1,500,000 and 2,200,000 passes). For the other investigated mixes have been recorded diagrams with similar shapes with different values. In relation with the Fig.1, one may observe that the main permanent sag deformations have been recorded on the strips corresponding to the wheel passes, whereas on the areas between the wheels and on the exterior of the circulated strips, rejection of material in the form of crests, specific to the rutting phenomena, have been recorded. The highest deformations observed on the right side of the diagram are corresponding to the inner wheel from the running assembly, this wheel being a motor one.

Further on, the evolution of the permanent deformations obtained by statistical processing of recorded data is presented in Fig.2, each of the five investigated mix being represented by distinct conventional signs:

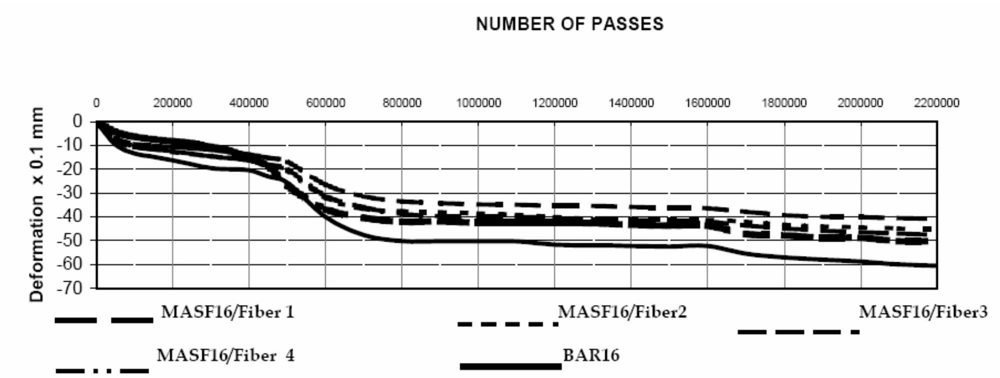

Fig. 2 Evolution of permanent deformations

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From the analysis of this diagram one may observe the following:

- there is a significant difference between the behavior of the mixes stabilized with fibers and that of the witness mix (BAR16) which presents the highest permanent deformations;
- five distinct stages can be observed in the evolution of the permanent deformations, in accordance with the number of cumulated number of passes as follows:
  - stage I: with a traffic between 0 and 50,000 passes, representing the supplementary consolidation of the mix, under traffic, characterized by a significant rate of development of the permanent deformations;
  - stage II: with a traffic between 50,000 and 400,000 passes, realized during the cold season of the year 2000 (February…May), characterized by a reduced rate of permanent deformations;
  - stage III: with a traffic between 400,000 and 800,000 passes, realized during the hot season of the year 2000 (June … September), characterized by a relative greater rate of the development of deformations;
  - stage IV: with a traffic between 0.8 x 10^6 and 1.7 x10^6 passes, realized during the cold season (October 2000 … May 2001), characterized by a very low rate (near zero) of development of permanent deformations;
  - stage V: with a traffic between 1.7x 10^6 and 2,2 x 10^6 passes, realized during the a relative hot period (June…September 2001), characterized by a rate of deformation higher then the preceding one;

For the quantification of the rate of accumulation of the permanent deformations, for each stage the slope of the specific evolution curves (deformation/ number of passes) have been calculated, these slopes being shown in Table 3.

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Table 3. The slopes of the evolution curve of the permanent deformations, on various stages of the experiment

The experimental sector	The type of mix in the experiment	The stage				
		I	II	III	IV	V
1	MASF16 with cellulose fiber 1	0.220	0.045	0.155	0.004	0.020
2	MASF16 with cellulose fiber 2	0.240	0.040	1.108	0.007	0.018
3	MASF16 with cellulose fiber 3	0.200	0.063	0.108	0.004	0.018
4	MASF16 with cellulose fiber 4	0.180	0.057	0.090	0.007	0.022
5	BAR16 (witness sector)	0.380	0.066	0.152	0.011	0.028

This evolution demonstrates the very strong influence of temperature reached in the asphalt layer on the development of the rutting phenomenon, this being also confirmed by similar experiments, conducted on the accelerated circular track at LCPC Nantes [14], where for the asphalt binder used in their experiment (penetration 50/70) a temperature level of 45°C, has been defined as a critical one for the initiation of the rutting phenomenon.

As the rutting distress was developed also along the circulated strips, longitudinal profiles have been performed along this direction, based on the maximum deformation values recorded during various stages of the experiment. Fig.3 presents the average permanent deformations of the pavement, in longitudinal profile, recorded during the testing on the experimental sector 1.

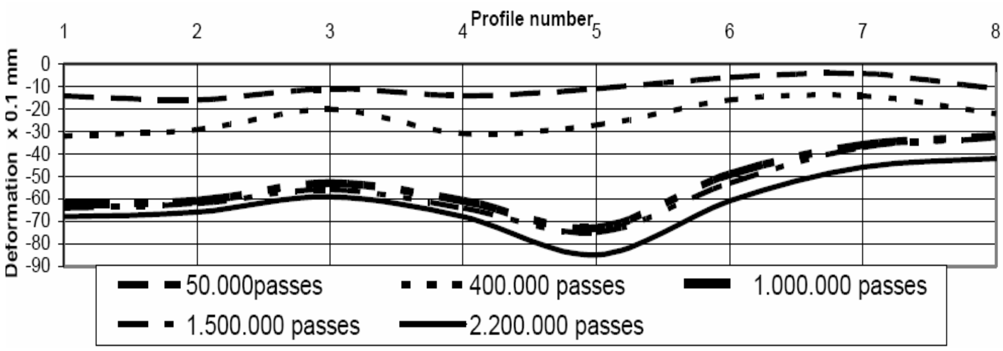

Fig.3. Average permanent deformations of the pavement, in longitudinal profile, recorded during the testing of the experimental sector 1

The maximum values of the depth of the rutting, recorded in longitudinal profile, at various stages of the experiment for each experimental sector and circulated strip are presented in Table 4. Table 5, presents the differences between the maximum a minimum depths of rutting, recorded in longitudinal profile on these sectors.

Table 4. The maximum values of the depth of the rutting, recorded in longitudinal profile, at various stages of the experiment for each experimental sector and circulated strip

The recorded traffic	The circulated strip	The experimental sector				
		1	2	3	4	5
$50x10^3$ passes	Exterior	20	8	16	10	20
	Interior	16	16	20	18	19
$2{,}2x10^6$ passes	Exterior	74	59	72	60	97
	Interior	85	66	79	68	85

Table 5. The differences between the maximum and minimum deformations recorded in longitudinal profile on each experimental sector

The recorded traffic	The circulated strip	The experimental sector				
		1	2	3	4	5
$50x10^3$ passes	Exterior	20	8	16	10	20
	Interior	16	16	20	18	19
$2{,}2x10^6$ passes	Exterior	74	59	72	60	97
	Interior	85	66	79	68	85

Finally the study was completed with the laboratory investigations on cores in order to assess the evolution of the asphalt mix properties under the total of $2{,}2x10^6$ passes of the standard axle load of 115 kN. A number of 36 cores have been taken from the experimental sectors and the mix susceptibility for rutting has been investigated at the Road Laboratory of the Romanian Center for Road Engineering Studies, by using the Wheel Tracking equipment, in accordance with the British procedures [16], adapted to the Romanian conditions [17]. These results [10] are fully confirming the main conclusions drawn from the measurements and investigations made on the wheel track, during the development of the experiment. Based on the general results obtained during this experiment and on other specific literature data [18], specific failure criteria and valuable recommendations have been developed [2],[10],[14],[15], for the use in the planning of new accelerated experiments [19], [20], or for road practice industry, in this country ort abroad [7].

6. CONCLUSIONS. RECOMMENDATIONS FOR ROAD PRACTICE

The following conclusions and recommendations for practice have been derived from the results of this experiment:

1. The laboratory tests performed with the aim of the design of the various mix compositions, or for their quality control during the process of laying and compaction, are attesting slight improvement of the physic and mechanical characteristics of the asphalt mixes stabilized with various types of fibers in comparison with those of the classical mix BAR16. Marshall stability of the stabilized asphalt mixes is significantly improved, but this can not confirm a possible reinforcement effect in case of the use of the textile fibers;

2. The performance, under the repeated passes of the standard axle load of 115 kN appreciated in terms of the values of permanent deformation(depth of rutting) of the asphalt mixes stabilized with various types of fibers is significantly improved in comparison with that of the classical mix, without fibers. It was difficult to make a performance classification between those four types of mixes stabilized with fibers. But was evident that the behavior of the asphalt mixes stabilized with fibers types 1, 2 and 3 was much better than that of the asphalt mix stabilized with fiber type 4., and this conclusion was made known to the decision factors of the Road Agencies, in order to be considered at the selection of materials in the future rehabilitation works.

3. Related with the evolution of the permanent deformations, in time under repeated traffic, the following conclusions can be drawn:

   - the effect of the supplementary consolidation achieved during the first stage of experiment (50,000 passes) became very clear, despite the fact that the temperature was relatively lower;

   - the development of rutting phenomena is strongly influenced by the high temperatures, the most important values of the rutting depth have been recorded during the first hot season, even so the maximum temperature level recorded during the experiment did nit reached the critical temperature level obtained during the similar French experiments [14];

   - during the second hot period, a new trend for the increasing of the rutting depth has been recorded, but at a lower rate, due to the relative low values of the maximum temperatures and also to the existing consolidation;

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4. The distress condition is characterized by both the shape and the depth of rutting in transverse profile and by its shape and evolution in longitudinal direction, along each sector, where, function of the attained values on may reach the complete failure of the structure. Thus, in case of the witness sector, realized with classical mix BAR16, severe trends of corrugations, with an amplitude of over 5 mm, has been observed after a traffic of $2.2x10^6$ passes of the standard axle load of 115kN, whereas on the other sectors this trend was very small (maximum 2..3 mm).

5. Based on the general results obtained during this experiment and on other literature data, specific failure criteria and valuable recommendations have been developed [2], [14], [15], for the use in the planning of new accelerated experiments [19], [20], or for road practice industry, in this country and abroad [7].

7. ACKNOWLEDGEMENTS

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• The Technical Council of National Administration of Roads for accepting and implementing the Technical specifications for the Asphalt Mixes stabilized with Cellulose Fibers used for the Construction of Bituminous Road Pavements;

• The Romanian Center for Road Engineering Studies and Informatics –CESTRIN, for the developing of NAR/ Specification No.539-98 (99)-2000 and for advance testing of asphalt pavement samples;

• The Research Center for Macromolecular Materials and Membranes from Bucharest, for providing various indigenous fibers for the experiment.

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The use of fly ash and volcanic tuff for the construction of the mixed road pavements

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Summary

The paper presents the research results on the properties of the various sorts of fly ash and volcanic tuff, extracted from Eastern Carpathian Mountains, in order to be use for stabilization of local materials, at the construction of mixed road pavement structures. This research has been undertaken in the frame of the Department of Transport Infrastructures and Foundations from Technical University "Gh. Asachi" Iasi. The results obtained on experimental sectors equipped with such mixed road pavements, constructed on the Accelerated Loading Testing Facility " Professor Dimitrie Atanasiu" and specific technical recommendations are also presented .

KEYWORDS: mixed road pavement structures, fly ash, volcanic tuff, alt-accelerated, loading testing.

1. INTRODUCTION

In the context of the actual economic and energetic crisis, it is necessary to apply new constructive solutions, capable to bring energy savings, reduction of deficient materials and to use, on a larger scale, of the local byproducts and materials. In the same time, the rational use of local materials involves the use, to a larger extent, of the stabilized aggregate mixes, as specific materials included in the composition of the mixed road pavements.

2. MATERIALS USED FOR THE STABILIZED MIXES

Romanian technical specifications [5] for the design and construction of road pavement layers stabilized with pozzolanic binders provide the use of natural aggregate (sand, ballast) and of the quarry aggregates including quarry byproducts. As binders, these specifications are recommending the use of various sorts of fly ash and of volcanic tuff.

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3. POZZOLANIC BINDERS

The use of puzzolanic binders, of some industrial byproducts and of volcanic rocks such as tuffs, largely spread in many countries such as France, Belgium, USA, etc, has reached now, in our country, an operational status. Pozzolanic binders are siliceous and silico-aluminaceus materials containing chemical compounds which are able to combine with some additives like lime, so that, in the presence of water , at the usual temperature to be able to give birth for new formations , less soluble in water and manifesting binder properties.

3.1. The thermo industrial fly ash

Fly ash is an artificial pozzolanic binder which results as a byproduct at the burning in air suspension of the fine grinded carbon, at temperatures varying between 1200 to 1500 ^{0}C. The ash is obtained on dry procedure, by using specific separators and electro-filters, after which is stored in big deposits. The fly ash involved in our experiment has resulted from inferior carbon combustion and is looks like a gray color fine powder.

The grading curves of fly ash, produced in Iasi and Vaslui are presented in Fig.1. In relation with this figure, one may observe that the Vaslui ash is finer than that of Iasi (75% passing through sieve 0.071mm, in comparison with 57%)

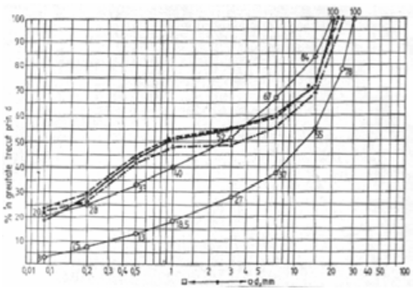

Fig.1. The grading of two sorts of fly ash

Physical characteristics of these two sorts of fly ash are presented in Table 1.

The use of fly ash and volcanic tuff for the construction of the mixed road pavements

Table1. Physical characteristics of the investigated sorts of fly ash

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Fly ash from sources :</td><td rowspan="2">Grinded volcanic tuff</td></tr>
<tr><td>Iasi</td><td>Vaslui</td></tr>
<tr><td colspan="2">Blaine specific surface , cm2/g</td><td>3490</td><td>3800</td><td>3620</td></tr>
<tr><td colspan="2">Apparent density , g/cm3</td><td>2.209</td><td>2.349</td><td>2.289</td></tr>
<tr><td rowspan="2">Bulk apparent density</td><td>Loose state</td><td>0.735</td><td>0.819</td><td>0.785</td></tr>
<tr><td>Compacted state</td><td>0.947</td><td>0.958</td><td>0.978</td></tr>
</table>

The chemical composition of the fly ash from those two sources and the technical conditions recommended by Romanian norms are presented in Table 2, from below:

Table 2. The chemical composition of the investigated sorts of fly ash

<table>
<tr><td rowspan="9">Chemical composition, %</td><td>MgO</td><td colspan="2">2.20</td><td colspan="2">2.10</td><td colspan="2">3.40</td><td>Max 5.0</td></tr>
<tr><td>PC</td><td colspan="2">2.29</td><td colspan="2">2.18</td><td colspan="2"></td><td>≤ 10</td></tr>
<tr><td>K_2O</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>1.3</td></tr>
<tr><td>Na_2O</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>1.3</td></tr>
<tr><td>SO_3</td><td colspan="2">3.76</td><td colspan="2">3.05</td><td colspan="2">2.72</td><td>Max 3.0</td></tr>
<tr><td>CaO</td><td colspan="2">5.60</td><td colspan="2">4.06</td><td colspan="2">5.40</td><td>Min 5.0</td></tr>
<tr><td>Fe_2O_3</td><td rowspan="3">$\Sigma = 90.05$ %</td><td>7.58</td><td rowspan="3">$\Sigma = 88.76$ %</td><td>7.98</td><td rowspan="3">$\Sigma = 89.70$ %</td><td>5.48</td><td rowspan="3">$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70$ %</td></tr>
<tr><td>Al_2O_3</td><td>32.42</td><td>27.50</td><td>34.62</td></tr>
<tr><td>SiO_2</td><td>50.05</td><td>53.28</td><td>49.20</td></tr>
<tr><td colspan="2">Name and source of the investigated binder</td><td colspan="2">Fly ash from Iasi (lignit)</td><td colspan="2">Fly ash from Vaslui (lignit)</td><td colspan="2">Grinded volcanic tuff Harghita</td><td>Technical conditions according Romanian specifications</td></tr>
</table>

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3.2. Grinded volcanic tuff

Tuff is a volcanic-sedimentary rock resulted from deposition and cementation of the volcanic ash. The main source from Eastern Charpatian Mountains is the Santdominic quarry. The raw material is presented under the form of a quarry aggregate, size 8-20mm. This aggregate is then grinded to obtain finer material, with a grading, similar to that shown in Fig.2. the grinding fineness, being of 67%. The chemical composition of the grinded volcanic tuff is given in Table 2. In relation with Table two, one may observe that this composition meets the technical conditions specified in the Romanian norms [4].

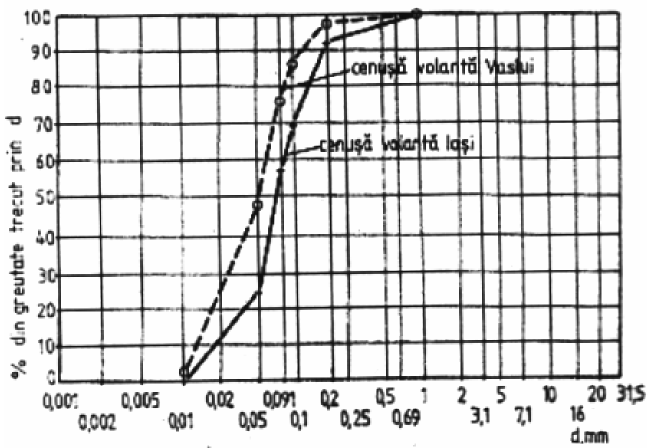

Fig.2. Grading of the grinded volcanic tuff

3.3. The hydraulic lime

The hydrated lime, furnished by the Bicaz factory, under the form of a fine powder has a content of calcium oxide (CaO) of 60,7% and a grading with a rest of 12,3% on the 0,09 sieve.

4. EVALUATION OF THE POZZOLANIC ACTIVITY

4.1.,[4]/ The modified ASTM Method

In accordance with this method the resistance to compression is determined on specimens realized from a mix of calcium hydroxide (one part) and uniform sand (two parts), compacted in cylinder molds having 5 cm diameter and 10 cm

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height, after curing in water at the temperature of 23 ^{0}C for 24 hrs and then at the temperature of 55 ^{0}C for six days.

The compression resistance, determined on cylinders, in these conditions , at the age of seven days , must be at least 0,55 N/mm, in order the ash to be considered as an active one. The laboratory positive results obtained by testing hose three types off pozzolanic binder investigated are presented in Table 3:

Table 3 the mechanical characteristics of the investigated pozzolanic binders

The type of the pozzolanic binder	R_c 7 at 7 days, N/mm^2
Fly ash / Iasi	0.96
Fly ash /Vaslui	0.90
Volcanic tuff /Harghita	0.67

5. A PROPOSED METHOD FOR EVALUATION OF THE ACTIVITY OF POZZOLANIC BINDERS

This method consist in determining the compression resistance at 28 days on specimens stored in wet atmosphere and at seven days for specimens stored one day in wet atmosphere and then on accelerated dry at 55 0C for the rest of 6 days. Test specimens are realized from mixes of 90% pozzolanic binder and 10% hydrated lime , brought at the optimum moisture content established according AASHTO (modified) Proctor procedure, on cylinders having the same dimensions as in the ASTM method. In both cases, according ASTM recommendations the resistance value has to be of at least 0.55 N/mm. The results obtained on these tests are presented in Table 4:

Table 4. Compression resistance for the investigated specimens

The type of mix	Curing conditions		
	normal		thermo-accelerated
	R_c (N/mm^2)		
	Age , in days		
	7	28	7
Fly ash/ Iasi (90%) + hydrated lime (10%)	0.37	0.58	0.55
Fly ash/ Vaslui (90%) + hydrated lime (10%)	0.37	0.55	0.54
Volcanic tuff Sindominic (90%) + hydrated lime (10%)	0.26	0.61	0.57

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6. NATURAL AGGREGATES

Natural aggregates of ballast type extracted from the Pascani quarry and quarry byproducts from Santdominic, Suseni and Chileni sources, complying with the Romanian technical conditions [5] have been used in the experiment.

7. THE STABILIZED MIXES

Four types of stabilized mixes have been used, as follows:

-Ballsat/ Siret stabilized with 25% Iasi/ flying ash

-ballast /Siret stabilized with 25% Vaslui/flying ash

-quarry byproduct/Sandominic stabilized with 8% volcanic tuff

-quarry byproduct/ Suseni-Chleni stabilized with 8% volcanic tuff

Grading curves of these mixes are presented in Fig. 2 the Proctor compaction characteristics are presented in Table 5 from below:

Table 5 . The Proctor compaction characteristics obtained for the four types of stabilized mixes

The type of mix	$\gamma_{d\ max}$, (g/cm^3)	W_{opt}, (%)
Siret ballast + 25% Iasi flay ashe	1.89	9.5
Siret ballast + 25% Vaslui fly ashe	1.863	9.5
Sindominc quarry by product + 8% volcanic tuff	2.345	8.5
Suseni - Chileni quarry byproduct + 8% volcanic tuf	2.283	9.98

The results obtained on compression tests, performed on cylinders prepared from these mixes and tested at 14, 28, 60, 90, 180 and 360 days are given in Table 6.

8. RESULTS OBTAINED ON ALT PILOT TESTS

Three types of road pavement structures has been conceived by using Siret ballast stabilized with 25%Valsui fly ash and used for the construction of thre experimental ALT sectors as follows:

-sector 1: foundation layer /20 cm ballast; base layer / 10 cm stabilized ballast; wearing course: 5 cm rough asphalt concrete ;

The use of fly ash and volcanic tuff for the construction of the mixed road pavements

-sector 2: foundation layer /20 cm ballast; base layer / 15 cm stabilized ballast; wearing course: 5 cm rough asphalt concrete ;

-sector 3: foundation layer /20 cm ballast; base layer / 20cm stabilized ballast; wearing course: 5 cm rough asphalt concrete.

These sectors were exposed to the accelerated traffic after a period of 60 dyes necessary for the curing of the stabilized mixes with fly ashes.

Permanent deformations under ALT tests have been recorded at various stages and the results are presented in Fig. 3.

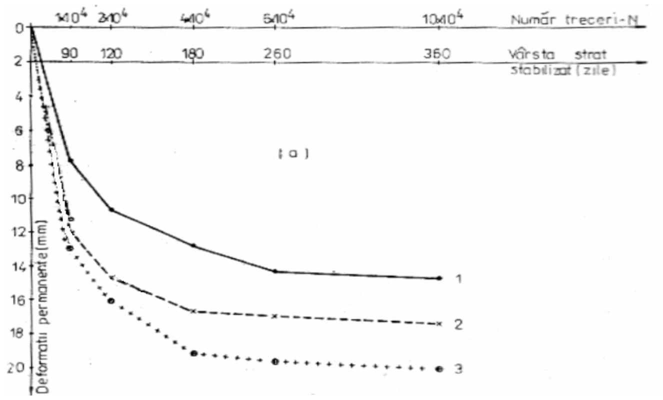

Fig.3 Permanent deformations under ALT tests, recorded at various stages of the experiment

In relation with Fig.3, one may observe that the more rapid accumulation of the deformation in the initial loading period till reaching the number of 4x10^6 passes of the standard axle load (11.5 kN), this limit corresponding with the age of 60…180 days , necessary for the complete curing of the stabilized mixes.

Table 6. Results obtained on compression tests, performed on cylinders prepared from these mixes and tested at 14, 28, 60, 90, 180 and 360 days

Technical conditions	R_{tg} N/mm^2	-	-	-	-	-	-	-
	R_c N/mm^2	Base course	1.3	2.2	-	-	-	-
		Foundation course	0.7	1.2	-	-	-	-
Suseni - Chileni quarry byproduct + 8% volcanic tuff		R_c N/mm^2	0.2	0.3	0.34	0.40	0.50	0.80
		R_c N/mm^2	2.3	2.5	3.5	3.9	4.2	6
Sindominc quarry by product + 8% volcanic tuff		R_c N/mm^2	0.2	0.3	0.35	0.4	0.7	0.75
		R_c N/mm^2	2	2.5	3.3	4	4.6	5.9
Siret ballast + 25% Vaslui fly ash		R_c N/mm^2	0.2	0.25	0.3	0.4	0.45	0.5
		R_c N/mm^2	1.6	2.2	2.75	3.2	3.7	5
Siret ballast + 25% Iasi flay ash		R_c N/mm^2	0.2	0.3	0.4	0.5	0.6	0.75
		R_c N/mm^2	1.4	.2.2	3.2	3.3	3.8	6.2
Age in days			**14**	**28**	**60**	**90**	**180**	**360**

8. CONCLUSIONS

- The fly ashes from sources Iasi and Vaslui used for the stabilization of the Siret ballast may be an alternative solution for the construction and rehabilitation of roads in this region of Romania;

-The grinded volcanic tuffs from eastern Carpathian Mountains (Harghita county) is also a good alternative for the realization of the stabilized mixes for stabilization of the quarry byproducts from sandominic and Suseni-Chileni, in order to be used for the construction of road pavement structures in the region ;

- The mixed road pavement structures realized with Siret ballast stabilized with Vaslui fly ashes have a satisfactory behavior under accelerated traffic , and thus they could be used for the modernization of the roads subjected to low and medium traffic.

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How to build on difficult foundation soils in Iasi County area

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Summary

Romania is a medium-sized country (23.83 millions ha), located in the south-eastern part of Europe. Geographically, plains and tablelands occupy 49.3 percent of the country area, hills occupy 30.2 percent, and mountains 20.5 percent.

Being the second largest city of Romania by number of inhabitants (after Bucharest), through its numerous historical, cultural and economic sites, also called "the museum-city", but also as an educational and business centre, Iaşi is the city of "Gh. Asachi" Technical University, we come from.

During the past decade, damage due to swelling action of swell-shrinking clays from Iaşi area, Romania, has been observed more clearly in some parts of Iaşi where rapid expansion of the city led to the construction of various kinds of structures.

In this study, a research program has been conducted to investigate the effect of remoulding and desiccation on the swelling behaviour of swell-shrinking clay and its swelling anisotropy, to estimate depth of active zone, to develop a simple technique in determining the magnitude of swelling based on water content of the soaked specimen after 24 and 72 h, and to produce predictive models which could be used to estimate the swelling potential of swell-shrinking clays from its mineralogical and simply measured engineering characteristics. A laboratory testing program was carried out using both undisturbed, and remoulded and desiccated samples selected from different locations.

KEYWORDS: difficult foundation soils, building.

1. INTRODUCTION

The relief of Romania varies from high mountains to low plains: these categories are represented by the Carpathian Mountains, the lower basin of the River Danube and the Western coast of the Black Sea with the most important wetland of Europe – the Danube Delta. Various natural resources and a large agricultural potential characterize the territory of Romania. After the Second World War and particularly under the communist government, the economic and industrial development of the

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country took place without any concern for environmental protection and sustainable use of mineral and human resources. Consequently, Romania faces at present numerous difficult environmental problems, which require urgent actions for rehabilitating the quality of the environment and for improving the quality of life. Solving or mitigating these problems is a large scientific and technological endeavour, which needs up-to-date know-how. Such efforts are surpassing the national capacity of Romania and thus can only be achieved by an efficient international co-operative programme.

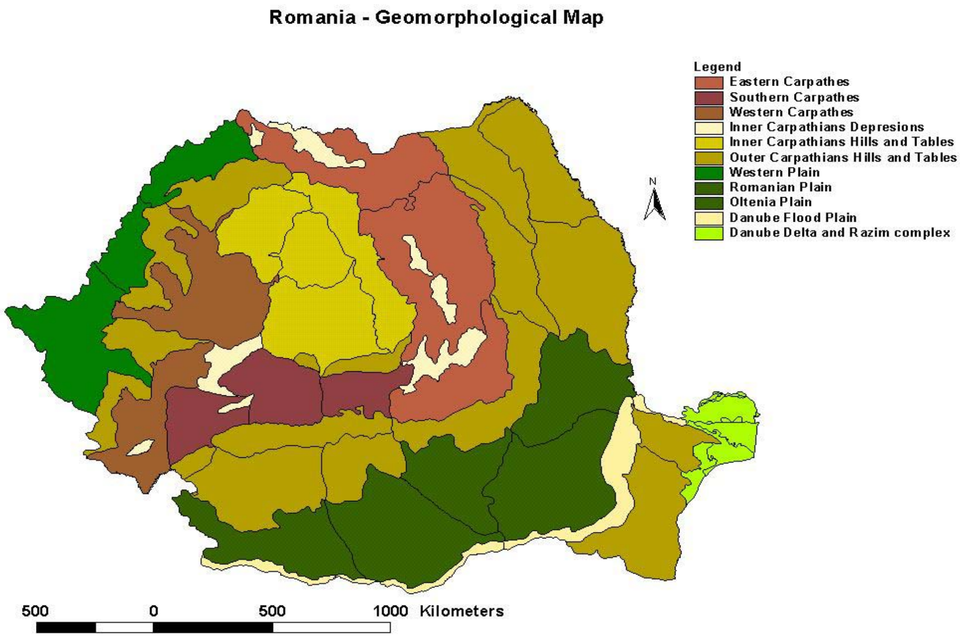

Fig.1 – Map of Romania and geomorphological map of Romania

Iaşi is placed in north-eastern Romania, more exactly where the 47^{o} 10' N parallel meets the 27^{o} 35' E meridian. Seated on seven hillock covering 3770 ha, its altitude varies between 40 m in the Bahlui Meadow, and 407 m in Păun Hill. It is the capital of Iaşi County, with a total area of 5,470 square kilometres, and an average altitude of less than 250 meters. On the eastern side, Iaşi County is neighbouring the Republic of Moldova.

From the point of view of the relief, the area of the town of Iaşi lies at the contact of two big geographical sub-units of the Moldavian Plateau: The Moldavian Plain and the Central Moldavian Plateau.

The landscape is dominated by plains, with very good agricultural potential, and by low hills, whose elevation increase going west, where they are to meet the Eastern

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Carpathians mountain chain. Generally, the vegetation and wild animals are quite typical to those of Central Europe.

The county is especially rich in building materials (sand, gravel, and limestone), pottery clay, as well as mineral waters well-known for their medical properties.

The capital city is crossed by Bahlui River, one of the county's four main rivers.

The general climate is temperate continental, with hot summers and freezing winters. Here are some characteristic values:

- Annual absolute maximum: 37 Celsius degrees
- Annual absolute minimum: -19.5 Celsius degrees
- Rainfall: is about 600 millimetres per year

The analyzed area is characterized by preponderance of two categories of difficult soils: contractive soils and macroporous soils. These two categories of soils complicate the selection of the locations and also complicate the design, the execution and the exploitation of all the buildings of the zone.

2. THE GENESIS AND STRUCTURE OF ALLUVIAL DEPOSITS FROM IAŞI AND CLIMATE FACTORS

To the geologic formation of the studied area take place deposits from Quaternary, Miocene, Cretacic, Silurian and crystalline beds. The zone's relief belongs to the category of fluvial and deluvial deposits of accumulation of Quaternary age.

Climatologically, Iaşi City and its surroundings belong to the temperate – continental climate. Atmosphere's dynamic is characterized by the preponderance of the influence of Europe's north – west and north air – masses, with abundant precipitations, those from south – east and east creating dryness weather and great differences between winter's and summer's temperatures. The thickness of the snow - bed is different every year and the storms and hailstones are constant meteorological phenomena in the area of Iaşi City, especially in July and August months.

3. PHYSICAL AND MECHANICAL PROPERTIES OF BAHLUI CLAYS

The observations made in the open holes of the studied zone in the summer time indicate that foundation soil is structured from brown plastic clay with thin zones of bluish and yellow colour. Until -1.10m depth the plastic clay is stiff and it can be digged. From this level to -1.90m the colour become darker, with ferruginous zones, with concretions of limestone, the clay is very stiff and is digged hard. This

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section allows the influence of the compressive process, realised by repeated drying and wetting tests of a clay soil. Between -1.90 and -2.40 meters the colour gets brown – black with ferruginous and bluish zones. Between -2.40 and -3.20 meters the water content of the soil keeps almost constant, the plastic clay has plastic consistency, is stiff and the colour is yellow with bluish – ferruginous zones. The natural water content varies from 28% to 43%. The results of the classification in function of geotechnical index are presented in Table 1.

Table 1 – Geotechnical index

Bore	Sample	Level	w_{nat}	**Plasticity**			**Grain-size**				**γs**		**Physical index**				
				Wf	**Ip**	**Wc**	2 µ	5 µ	1 mm	2 mm	Pic	Gr	γg	γu	n	e	S
		m	%	%			%				g/cm^3		g/cm^3		%		
S1	1	1.0	28.0	23.8	59.7	83.5	45	21	32	-	2.75	2.69	1.69	1.31	52.4	1.10	0.701
	2	1.5	30.0	27.0	46.8	73.6	3	18	33	-	2.72	2.69	1.74	1.40	51.1	1.04	0.783
	3	2.0	40.0	36.4	52.5	88.9	41	21	30	-	2.83	2.69	1.74	1.24	56.3	1.29	0.880
	4	2.5	35.4	26.5	55.5	82.0	46	23	30	-	2.76	2.69	1.76	1.30	52.7	1.11	0.875
	5	3.0	36.4	30.4	53.4	83.8	56	13	29	-	2.74	2.69	1.89	1.23	55.2	1.23	0.810
S2	1	1.0	40.7	29.7	55.2	84.9	54	18	24	-	2.74	2.70	1.76	1.25	54.4	1.19	0.936
	2	1.5	36.6	26.3	59.1	854	49	18	30	-	2.76	2.70	1.82	1.33	51.8	1.07	0.937
	3	2.0	36.7	25.8	58.0	83.8	44	22	31	-	2.77	2.70	1.82	1.35	51.4	1.05	0.962
	4	2.5	35.9	24.4	65.7	90.1	46	24	27	-	2.79	2.70	1.82	1.33	52.5	1.10	0.912
	5	3.0	33.7	22.5	59.5	82.0	47	22	30	-	2.81	2.70	1.87	1.40	50.3	1.01	0.936
S3	1	1.0	42.9	34.3	61.6	95.9	46	26	25	-	2.83	2.70	1.77	1.25	55.9	1.27	0.959
	2	1.5	42.3	31.5	74.7	106	55	22	20	-	2.80	2.70	1.78	1.26	54.6	1.20	0.984
	3	2.0	43.0	32.6	60.5	93.1	44	23	29	-	2.76	2.70	1.75	1.23	55.6	1.25	0.948
	4	2.5	39.8	26.2	76.3	103	40	24	30	-	2.74	2.70	1.78	127	53.4	1.15	0.949
	5	3.0	38.8	31.7	60.0	91.7	46	22	29	-	2.77	2.70	1.82	1.33	52.0	1.09	0.982

Taking into account the plasticity (Cassagrande line A), the Iaşi clay is in the category of inorganic clay soils with high plasticity.

The grain - size composition and distribution classifies the soil in plastic clay, the clay fraction being between 61% and 82%. This classification is also verified by the ternary diagram, which places it in the zone of plastic clays.

Natural unit weight is 1.67 g/cm^3 – 1.69 g/cm^3 ;

Dry unit weight is 1.23 g/cm^3 – 1.35 g/cm^3 ;

Porosity, n, has a great variation: 50.3% – 56.3% :

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Degree of saturation is 0.701 – 0.984.

Swelling processes being a consequence of wetting processes, the water absorbed by the hydrophilic swelling body is followed by heat of absorption. Taking into account the amounts of the heat of wetting used as index for the recognition of the very active clays (which presents volume changes at water content changes) the soil activity may be classified.

Thus, for heats of wetting of more then 7 cal/g the soils are considered active and very active.

Knowing the amounts of the total heat of swelling, we calculated the water content which corresponds to the adsorbed water. We also calculated the amount of specific surface, which is between 343mp/g and 270.5 mp/g. Experimentally testing the total heat of wetting as geotechnical index, we drew up the conclusion that the clays from Bahlui Plain are placed in the very active soils category and from the point of view of shrinkage and swelling in the category of very swell – shrinking soils.

4. THE STUDY OF SWELL – SHRINKING SOILS

4.1. The study of shrinkage phenomena

Many researchers analyzed the shrinkage and swelling behaviour of the clay soils. The number of joints or cracks per volume and their dimensions increase accordingly to the proximity of the soil's upper surface. Therefore, the most adequate geotechnical index, which characterise the properties of these clays are the shrinkage coefficients. There are three shrinkage coefficients: α_l , α_s , α_v . The graph water content versus geometrical dimensions before and after drying (dimensions of length, surface and volume) marks some straight lines which slope is precisely the shrinkage coefficient (fig.2, fig.3 and fig.4). The montmorillonitical clay of Iaşi we obtained the following values: $\alpha_l = 0.52$, $\alpha_s = 1.17$, $\alpha_v = 2.03$.

4.2. The study of swelling phenomena

In certain conditions, absorbing water, the shrinkage clays present volume expansions. If the volume expansions are limited, they produce remarkable swelling pressures. The experimental tests realised on undisturbed clays draw curves like those shown in fig.2, fig.3 and fig.4 which represent the line between pressure p, water content w and volume V. These curves propose a variable moisture index depending on water content.

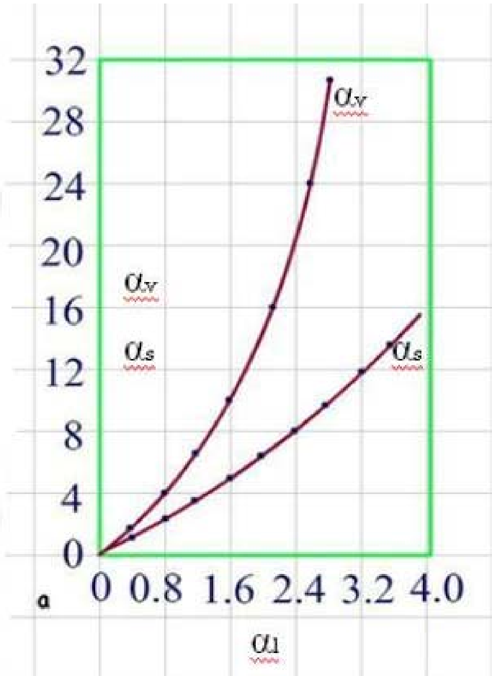

Fig.2 – The influence between shrinkage indexes

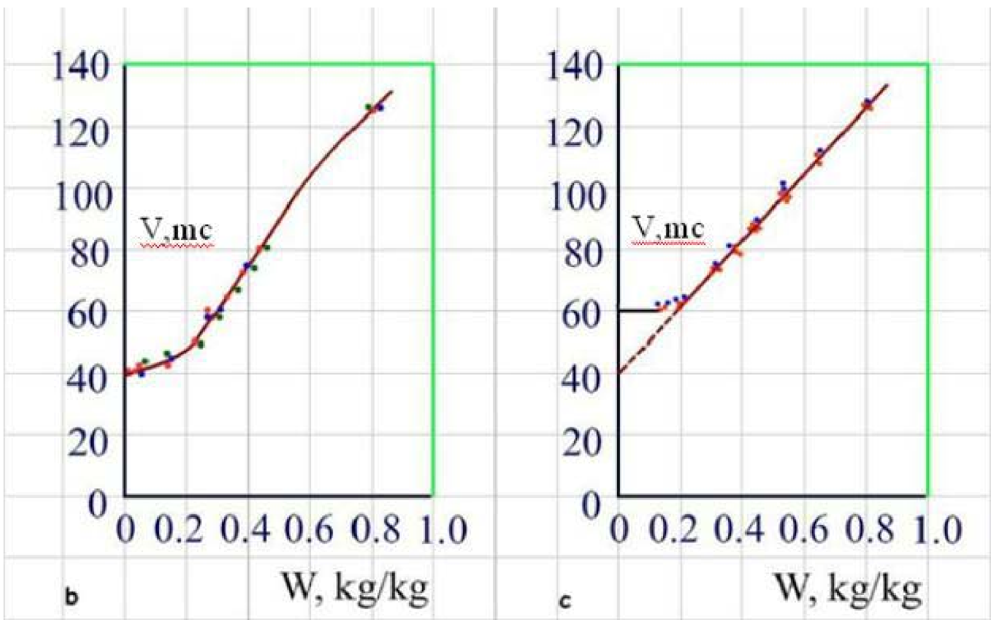

Fig.3 and 4 – Volume variation in function of water content, at continuous drying and at repeated dryings.

Experimental tests for establishing the swelling pressure are made in triaxial apparatus or in special adapted odometers. Like in the study of shrinkage, the swelling at higher water content must be a preoccupation of those who place structures on such soils. Experimental results and the observations made indicate that the clay from this area produces volume changes, movements of the ground, respectively, which are in connection with the transmitted pressure and with water content.

In conclusion, on Bahlui clays we can admit:

- The plasticity index, the grain – size composition and analysis, consistency index, activity index place these soils in the category of active and very active soils.
- The chemical – mineralogical study of foundation course from the plain Bahlui River, colour's reactions, the studies on electron microscope and the thermodynamics analysis led to the conclusion that most clay minerals are from the groups of montmorillonite and hydrated mica.
- The heat of wetting places the clay in the category of the swell – shrinking soils.
- The experimental research allows an improvement of the method for establishing the shrinkage coefficient. The elimination of the water content must be done slowly because the water content must be uniformity distributed in the sample. The increase of water content leads to important increases of the volume. The swelling depends on water content and pressure.
- The use of remolded and desiccated specimens seems to be a better approach in swelling tests for achieving more reliable swelling parameters. The swell pressures obtained from the remoulded samples showed better correlations with mineralogical, index and physical properties when compared to swelling percent and swell indices, such as free swell and modified free swell index.
- On this basis and considering its use in design, it can be concluded that the swell pressure is a better parameter for quantifying the swell potential.
- On the basis of the experimental results, we compute the swelling volumetric coefficient. In the field of 1 – 20 daN/cm^2 the values of the volumetric coefficient vary between -0.2 and 1.0 .

A hazard map showing the area distribution of high and very high expansive soils for the city of Iaşi is considered to be a very important tool. It is hoped that this map will be a useful tool for planners and engineers in their efforts to achieve better land use planning and to decide necessary remedial measures. Preparation of such a map based on swelling pressure or swelling percent, which are determined through expensive laboratory tests, takes long time. Therefore, the use of the predicted models seems to be more practical tools for this purpose. A study by the authors for the preparation of a map of swell potential for Iaşi City by considering the predictive models is in progress.

4.3. Recommendations regarding foundation execution

- The depth of foundation must be established in order that the variations of the water content have no influence upon the swell – shrinking phenomena. Thus, in the area of Bahlui Meadow this depth of foundation must be at least 2m.

- The execution of tree – plantations and the public utility equipment in the areas with shrinking soils must be realized taking into account the amplitude of ground movements caused by water content variations.

- When the depth of foundation of 2m cannot be respected, for the swell – shrinking soils of the area we must study the transmission to the ground of the effective pressure, in function of foundation pressure.

5. THE STUDY OF MACROPOROUS SOILS (LOESSOIDAL SOILS)

5.1. Conditions of loessoidal soils

Iaşi City is at contact of two areas, different from geomorphologic point of view – The Jijia Depression, The Bahlui Depression and The Moldavian Plateau. Iaşi City develops and extends on the cliffs and on the Valley of Bahlui River. The loessoidal deposits are on the upper cliff and on the medium cliff, which include areas of Copou Hill, Şorogari Hill and Ciric Hill.

The loess deposits from Iaşi area have the follow stratification: the surface is formed by a vegetable layer with fill here and there. It follows passing beds to the form bed of the deposit, with sand layers and transition silty clay between Quaternary and Sarmatian. The loessoidal underlay is sarmatian’s clay marl.

The plasticity of the loess of Iaşi is medium with yield limit between 30 and 50. The thickness of loess layer varies between 8 m and 11 m, with a peak value of 24 m in the north – west of the city.

The level of underground water presents variations: 11 – 16 m in the upper cliffs and 5 - 12 m in the medium cliffs with low rate flow. The loesses from Iaşi area and from the basin Jijia – Bahlui are alluviums transported and deposited in Pleistocene over the clay marls from Sarmatian.

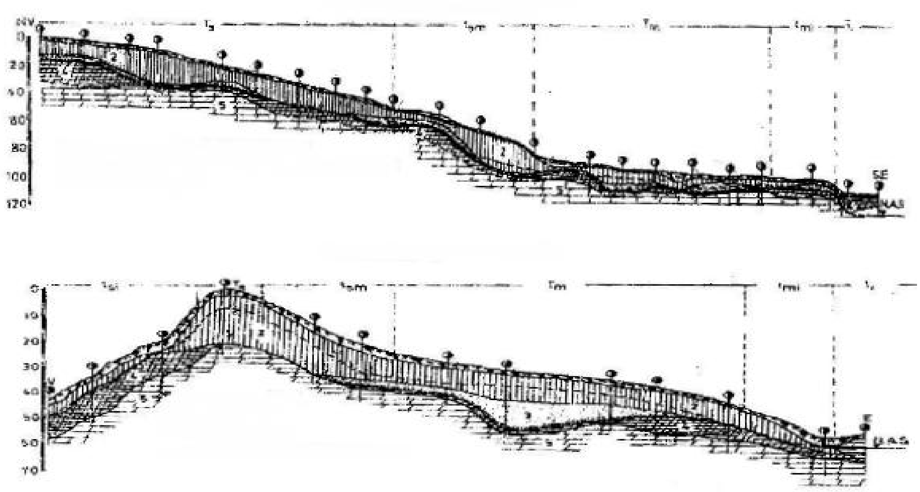

Fig.5: Extension of macroporous soils from Iaşi area

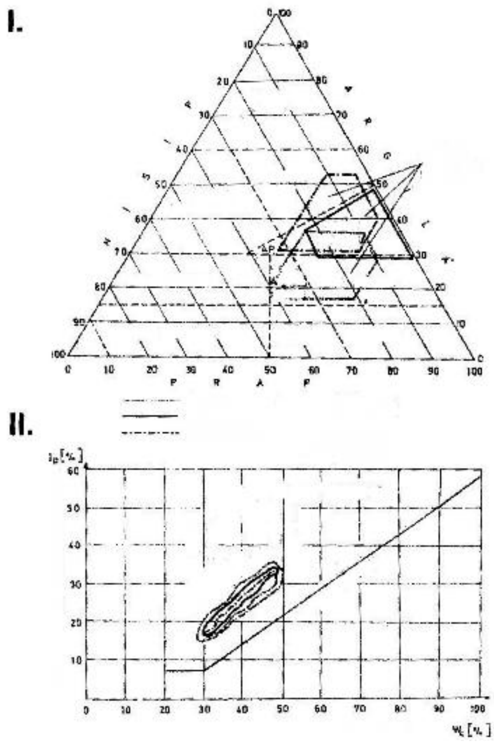

Fig.6 From the grain – size point of view the loess of Iaşi is represented in the ternary diagram

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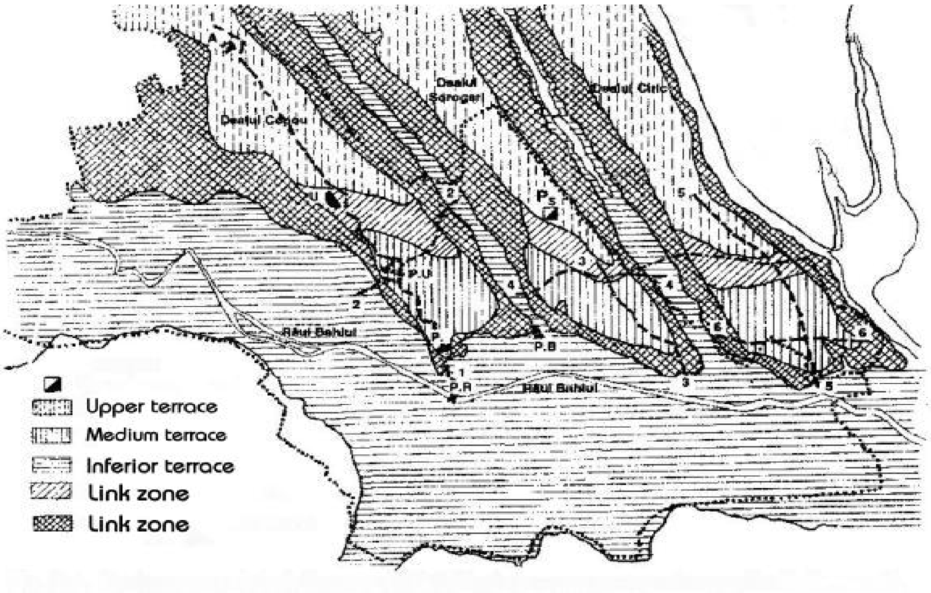

Fig.7: The loess of Iaşi presents more amounts of clay in the zone of Copou Hill

The specific properties of loessoidal rocks (high porosity, flocculated structure, accumulations of calcium carbonate, yellow – brown colour) formed due to a specific process of macroporous soils.

5.2. Foundation conditions

- The necessity of improvement of the macroporous soils.
- The compulsory check of constructions built on these soils at the effects of the complementary loads induced by the non – homogeneous settlements.
- The diminution of the length of the constructions built on these soils (settlement joints) especially for the soils capable of important total settlements.
- The checking of the systems of soils consolidation taking into account the analysis of relative bending and the analysis of average settlement.
- The limitation of non – homogeneous settlements taking into account the structure's configuration.
- The utilization of computational methods to establish the soil's deformations, different from the structure's deformation.

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- The ensuring of the stiffness and of the solidity of the substructure allowing the computations of the unequal settlements.

Building on locations with difficult foundation soils requires a distinct attention (in design, execution and exploitation) in order to choose the right structure and foundation and to pursue and keep in time these buildings.

Analyzing the geologic column from different locations we observe the nature and the properties of the layers and the expected sliding or some others geologic phenomena which would lead to the building's collapse.

Analyzing the different methods used in order to know the depth of active zone, we must grant a distinct attention to the macroporous soils, to the shrinking soils, to laboratory and in situ tests, in order to elaborate accurate solutions for foundations and for the co – operation soil – foundation – structure.

For these soils we must do more complex studies, in order to establish some properties which may influence the strength, the stability and the costs of the building (compressibility, swelling pressures, shrinking pressures, flood settlement).

The costs of the analysis of the soil's properties may lead to the decrease of the properties of these soils.

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