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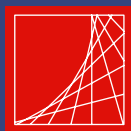
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INTERSECTIONS

**Transportation Infrastructure
Engineering**



"Matei - Teiu Botez"
Academic Society
Iasi, Romania



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Letter from the Editor

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First of all, from behalf of the Editorial Team, I'd like to welcome all readers of this first annual issue of **Transportation Engineering Infrastructure**, hosted by the new electronic edition of the **Intersection Journal**. Our editorial team is intending to feature articles of innovative and timely research and development activities in all modes of transportation infrastructure. Brief new items of interest to the academia and transportation community will also be included, along with profiles of transportation professionals, national and international meeting announcements and summaries of new publications in the field of transportation infrastructure. Before entering into the presentation of this number, I'd like to express our deep thanks to the following distinguished professionals from abroad, who kindly accepted to guide and to support us, as members of the Editorial Board of our journal : **John B. METCALF**, Professor of Civil Engineering at Louisiana State University, from United States of America, **Alex VISSER**, Professor of Civil Engineering at The University of Pretoria, Republic of South Africa and **Paolo PEREIRA**, Professor of Civil Engineering at The University of Minho, from Portugal.

This first issue is opening with a comprehensive view of the transportation engineering, as it exists today and can expect to evolve with the beginning of this new century suggestively entitled: "**Transportation Engineering, actual Status and Future Trends**". This presentation is based on a synthesis of various published papers by internationally recognized experts fully engaged in the progress of transportation engineering, emphasizing the main aspects of future developments of education in the transportation engineering field and the new challenges addressed to the "transportation professionals" and educators.

In their paper, entitled : "**Considerations on the Geometric Design of Low-Volume Roads**", professors **Horia Gh. ZAROJANU** and **Ioana VLAD** , both from Technical University "Gh. Asachi" of Iasi, are presenting the technical, economic and social criteria for justifying the adequacy of the new low-volume roads, in Romania. In accordance with their views, a "strategic policy" design of a local road infrastructure is justified for a minimum 15 years of service life, while a "tactic policy" may be adopted when designing the road structure. The design principles of low-volume roads are presented, taking into account the local conditions, including the ecological ones, emphasizing that both design and construction of new low-volume roads has to be framed into the concept of durable development.

With her study entitled "**Studies of the bitumens behavior at low temperature**", Doctoral student Engineer **Vasilica BEICA**, an outstanding and experienced researcher from the Romanian Center of Road Engineering Studies and Informatics – CESTRIN Bucharest, brings to the attention of the specialists, the different behavior at low temperature of two original bitumens. Beside the positive fact that polymer modification improves breaking properties of both bitumen, she found that modification affects differently the PG performance grade. As in Romania, where the climate is a continental



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one with severe winters and very hot summers the minimum pavement surface temperature is different, depending on the geographical location of the road, in order to achieve high performance and long lasting pavements, she recommends that only bitumen having the proper PG should be used for each specific geographical area. Beside its theoretical and practical importance this study, undertaken as part of a doctoral study, may be considered as an important new step and significant contribution of the author, to the actual process of implementation of the SHRP/ Superpave - Performance Based Specifications for the Asphalt Binders in Romania and in Europe.

After this series, this issue presents other significant research results undertaken in the field of transportation infrastructure engineering.

Thus Dr. Karel Pospisil, from the Czech Transport Research Center (Centrum Dopravního výzkumu-CDV) presents the actual trends of research, emphasizing the reliability, lifespan and safety of transport, imposed by the actual social and economic conditions, characterized by continuing decrease in the amount of material and energy sources. Significant research results, obtained by addressing these trends, in the fields of geotechnics, technology of concrete and non-destructive structures testing are described.

Another young and enthusiast researcher, Joseff Stryk, from the same Czech research institution together with his collaborators, Karel Pospisil, Marta Korenska and Lubos Pazdera, presents a very interesting and efficient "New Non-Destructive Diagnostic Method of Bridges".

The researches P. Ampe, J. De Corte, R. De Vierman from Vakgroep Bouwkunde Laboratorium voor Materiaalonderzoek, Belgium, show that: "dans le cadre de l'étude consacrée aux causes d'affaissement de recouvrements composés de petits éléments, maintes fois constatés sur site, ont effectuées dans le Laboratoire d'étude des matériaux, des essais dynamiques ayant pour objet des revêtements en pavés. Les dommages sont fréquents sur les axes chargés, éventuellement en combinaison accueillant UN trafic lourd, tels les récentes traversées de communes. Les essais en laboratoire avaient comme objectif de simuler un certain nombre de situations critiques potentiellement comparables aux situations sur site et d'observer le comportement du lit et des éléments en de pareilles circonstances. Afin de fonder les observations expérimentales par la théorie, un certain nombre d'essais et de situations de mise en charge furent numériquement simulées sur base de calculs analytiques. Cette approche théorique permet de proposer un certain nombre de formules pour la détermination de la charge maximale. L'article présent traite uniquement de la partie expérimentale. La partie analytique fait l'objet d'une autre contribution."

Finally a young Romanian physicist, Marian Peticila from the Romanian Center for Road Engineering Studies and Informatics – CESTRIN presents in this issue the results obtained by himself and his collaborators professors Vasile Tripadus and Liviu Craciun from the IFIN-HH, on the research focusing on the determination of the carbon/hydrogen ratio in bitumen using a prompt neutron gamma activation analysis. With their paper entitled "Determination of the Carbon/Hydrogen Ratio in Bitumen, Using Prompt Neutron Gamma Activation Analysis", they demonstrate a potential application of PGNA method that "allows fast determination of colloidal index of bitumen compounds by a very fast analysis of hydrogen and carbon content". The H/C ratio thus determined is then correlated with the colloidal index, using a regression analysis.



State of the Art and Future Trends in Transportation Engineering

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Summary

This paper intends to present a synthesis and a comprehensive view of transportation as it exists today and can expect 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, education, environment, intelligent transportation systems

1. TRANSPORTATION CHALLENGES FOR OUR GENERATION

To mark the beginning of this new millennium, the various transportation bodies and committees from the world (TRB,¹ ERC², AARB³, 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] 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.

¹ TRB-Transport Research Board (USA)

² ERC-European Road Conference

³ ARRB- Australian Road Research Board



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2. TRANSPORTATION 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 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



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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 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



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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 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,



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efficient transportation system capable to meet not only Romania's but also the Europe Community's—needs, in the actual highly competitive environment.

4. TRANSPORTATION RESEARCH. CURRENT PRACTICE AND TRENDS

There has long been widespread recognition that transportation is the foundation of 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 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



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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 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 COST⁴ and SERP⁵

⁴ COST-Cooperation Scientifique et Technique

⁵ SERP-Strategic European Research Program



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programs, and through various research bodies such as FEHRL⁶, ECREDI⁷, 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 OCDE⁸ 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 laying 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.

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

⁶ FEHRL -Forum of European Highway Research Laboratories

⁷ ECREDI-European

⁸ OECD- Organization for Economic Cooperation and Development



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recent study by FHWA⁹ 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 over 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 (IRRDP) 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 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

⁹ FHWA- Federal Highway Administration, USA



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

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Considerations on the geometric design of low-volume roads

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Summary

Technical, economic and social criteria have to be considered for justifying the adequacy of the new low volume roads, in Romania. The high investment costs in this field are the consequence of the non satisfactory viability state, which characterizes the majority of the local road network of Romania, where graveled roads represent more than 25,000 km, and earthy roads represent more than 8,500 km. Only 10% of the local roads are modernized, 30% are provided with semi-permanent pavements, and most of them have an exceeded service life. In accordance to a "strategic policy" design of the infrastructure of a local road is justified for a minimum of 15 years service life, while the "tactic policy" may be adopted when designing the road structure. The paper presents the design principles of low-volume roads, taking into account the local conditions. There are emphasized the following: the local road functions - both public and social ones, the required conditions for the geometric design, the importance of multi-criteria methods as economical tools. The design principles according to the Romanian technical provisions for horizontal and vertical alignment, and that of the cross sections are also discussed. The concept of the ecological resistance is also presented. The conclusions emphasize that both design and construction of a low volume road has to be framed into the concept of durable development.

KEYWORDS: geometric design, low volume roads, ecological resistance, multi-criteria analysis

1. INTRODUCTION

According to the official classification, most of Romanian low volume roads are local ones and they are subdivided as county or communal roads. The design of a low volume road, aimed to ensure the accessibility and mobility of people in localities placed in rural or small urban areas involves both technical and an economical aspects. The economical aspect is emphasized by the actual poor technical condition of the existing local road network. According the technical



Considerations on the geometric design of low-volume roads

classification, the low-volume roads are usually included in the 4th and 5th classes. The hourly traffic flow corresponds to the 50th hour of the year. Function of the specific of the road, in case of a staged construction strategy, the design traffic flow corresponding to the 100th - 200th hour may be adopted.

2. DESIGN PRINCIPLES

The design speed has not an intrinsic meaning; its significance is correlated to the safety and comfort parameters. These parameters have to be correlated with the road function, in order to assure a reasonable the ratio between the technical provisions of both low and high volume/speed roads.

The adoption of minimum design parameters, (e.g. R_H - the radius of curve in horizontal alignment, R_V - the radius of the convex curve in vertical alignment, etc) does not lead compulsory, to the most economic alignments.

The design of the infrastructure of a local low volume road according to a "strategic policy" is justified for a minimum of 15 years service life.

A "tactic policy" may be adopted when designing the road structure over 3...5 years, with the provision of adequate structures, capable to permit the practice of successive strengthening technique, according to the traffic evolution.

The design and construction of the road route in plan, is usually justified for final design parameters, while the construction of the road may be realized in stages if this approach is justified from technique and economic point of view. Also lateral safety zones must be provided as important elements related to the environmental impact, according to the durable development concept.

The exceptional values of the geometric functions should be adopted in order to avoid some very expensive works and/or for the protection or the fitness of the route on the compulsory points.

The criteria for the evaluation of various design alternatives and of the opportunity of the scheduling of investments have to be completely different from those adopted for important roads, because in the rural media, the road fulfills not only a "public" function, but first of all a " social service ", similar to those schools or a medical centers, etc. In this respect, some criteria related to the social function of a local road could not be quantified from an economic point of view, so that the role of multi-criteria methods of analysis to be increased and in some cases to become compulsory for analysis of such projects.



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3. THE DESIGN SPEED

The design speed is correlated to the technical road class and also to the relief type, as it is presented in Table 3.1.

TABLE 3.1. Design Speeds for Low-Volume Roads

Technical Classe	Design Speed (km/h) for:						Remarks
	Flat area		Hilly area		Mountain area		
	A	B	A	B	A	B	
IV	60	50		40	30 ^(*)	25	(*) A 20 km/h speed is required in the main curve of a serpentine
V	50	40	40	25	25 ^(*)		

The speed values from the "A" column may be increased with maximum 20 km/h if no supplementary costs were involved. The difference between the design speeds of two adjacent running sections must not exceed 10-20 km/h. The base speed defined as the minimum design speed along the road route, must not be less than the speed values specified in column B. These values are admitted in case of severe conditions of the route or may be imposed by the adjacent road environment conditions.

4. SPECIFIC GEOMETRIC CONDITIONS

4.1. Horizontal alignment.

The lengths of progressive connections are established based on the dynamic comfort criteria, the optical comfort criteria being not justified for the local roads, because of the limited speeds. The exclusive use of the clothoid is not justified in case of high frequency of compulsory points, under difficult relief condition, in the protected zones at the crossing rural localities (this last one being a general characteristic of low-volume road network in Romania). Other progressive transition curves can be used as follows:

- The clothoid with a variable modulus defined by the equation:

$$\rho s^n = A^{n+1} \quad (4.1)$$

The acceleration rate, j is defined as:



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$$j = v^3 \frac{n \cdot s^{n-1}}{A^{n+1}} \text{ [m/s}^3\text{]} \quad (4.2)$$

where:

P [m] is the curvature radius of the arc s , n is an exponent resulted from the conditions imposed by the connection, v is the vehicle speed expressed in m/second. The equation (3.1) corresponds to a family of curves, enabling the adoption of rational and efficient solutions for the road route.

- The circular arc of double radius enables the reduction of the progressive transition length, leading to a value of j coefficient greater than 0.5 m/sec^3 ;
- The cubic parabola for the easiness of the field operations;
- The acceleration-deceleration curves which may assure the conditions of progressive transitions for zones with frequent changing the design speed (situation which may be often encountered in case of local roads)

4.2. Vertical alignment.

Special gradients are adopted on limited distances only when climatic conditions are favorable. The solution involving the traveling of the ascending grades by inertia, with the reduction of the vehicle speed according to the prescribed limits, may be taken into consideration even if this solution is not recommended from the point of view of the optical comfort. Emergency spurs may be also considered for particular cases of significant extended gradients. The necessary stopping sight distance must be correlated with the maintenance conditions according to the pavement type. Thus, a poor maintenance and severe damaged road surfaces or a road with a reduced skid resistance will require longer braking distances.

4.3. The transverse profile

Any widening is provided at the interior of the curve, but in exceptional cases the following solutions may be considered:

- Widening of each traffic lane;
- Widening of the carriage way, on both sides.

In case of small cuttings (depth of cut less than 2 meter), the adoption of 1/10 slope will be justified in agriculture zones, in all areas susceptible for drifting snow and for the crossing of the agriculture areas in order to assure the access of agriculture equipment.



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5. THE USE OF MULTI-CRITERIA, MULTI-ATTRIBUTE METHODS FOR THE ANALYSIS OF VARIOUS PROJECT ALTERNATIVES.

Each project alternative is characterized in terms of various max/min criteria, either numerical or qualitative ones for the last ones being adopted an adequate value scale. Some examples of the multi-criteria analysis are presented in Table 5.1.

TABLE 5.1. Examples of Criteria for Multi-Criteria Decisions

Criteria		
Maximum	Technical	Traffic volume / Induced traffic Design speed /Base speed Minimum radius/ the average value in horizontal alignment Compensated earthwork volumes
		The rate of people with following accessibility: 30 minutes for daily activities; 60 minutes for weekly activities 120 minutes for monthly activities
		The effective/equivalent length of the route; The total length containing maximum/exceptional gradients; The weighted average gradient through total length ; The earthwork volume: total/ worked under adverse, or unfavorable conditions; The value of the total investment; Actualized total cost;
Minimum	Economical	Equivalent costs ; The term for the recovering of the initial investment;
		Number of days with traffic closing during the winter period; Number of days with traffic restrictions during the winter time ; Number of days with traffic closing due to floods;
		Agriculture and forest area to be expropriated; Ecological resistance Surfaces temporary extracted from the agriculture circuit.

The ecological resistance R_i enables a global characterization of various project alternatives from the point of view of the environmental impact.

$$R_i = (1,0 - C_i^+) / C_i^+ \quad (5.1)$$

Where:

$i = 1,2,\dots,m$

m- the number of the criteria ;



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C_i^+ - the relative difference from the ideal solution, obtained by using the method of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ;

The hierarchy of the various alternatives is established according to the ascending R_i values.

6. CONCLUSIONS

- Design of the low volume road infrastructure is justified, based on a strategic planning for a time horizon of minimum 15 years. For the structural design, a tactical planning for a period of 3...5 years may be adopted in case of financial constraints;
- The analysis criteria of various project alternatives and those undertaken for the evaluation of the opportunity and scheduling of investments, applied for local roads must be different from those applied for important roads, because in the rural medium, the roads represent not only a public service but mainly a social one. The use of multi-criteria methods for decision is useful and compulsory in some cases;
- For the appropriate fitness of the road route in the compulsory points, with the avoidance of the protected zones, the use of the special progressive connections is justified;
- Taking into consideration the specific nature of the areas crossed by the local road routes- rural localities, the road impact on the environment must represent one of the most significant design criteria.

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Studies on the bitumen behavior at low-temperature

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Summary

Because the Romanian climate is a continental one, with rough winters and hot summers, this work is a study upon low temperature behavior of the indigenous bitumen with 60/80 and 80/100 penetration grade, original and modified, coming from two different refineries, using Fraass breaking test and SHRP creep test with Bending Beam Rheometer.

The study shows a different behavior at low temperature for two original bitumens. Polymer modification improves these bitumen's breaking properties on both bitumen, but it affects differently the PG performance grade, respectively for RP bitumen, the modification doesn't bring important changes on low temperature PG, the PG remaining the same and for RA bitumen the PG to low temperature is improved by polymer modification.

As in Romania the minimum pavement surface temperature is different, depending on the area, bitumen having the proper PG must be used for each area.

Keywords: low-temperature, polymers, SHRP, stiffness, thermal cracking

1. INTRODUCTION

At high temperature the bitumen behaves like a liquid and flow and at low temperature it behaves like an elastic solid and becomes stiff [1]. At the temperature in which most pavements endure the traffic, the bitumen is a viscoelastic material that is it behaves like a viscous liquid and elastic solid simultaneously.

As in Romania the pavement are working in rough climate condition (very hot summers and low temperature winters) as we know the bitumen stiffness at low temperature leads to the apparition of cracking in the pavement, this study's purpose is the original Romanian and polymer modified bitumen's low temperature behavior, using Fraass breaking point test and SHRP creep test with Bending Beam Rheometer.

With the BBR equipment there have been determined the S stiffness module and the m-slope at a 60 s loading time. These parameters have served at PG



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classification in concordance with SHRP specification. It is reminded that to prevent the bitumen's stiffness caused cracking phenomenon the SHRP specification recommend a max. Value of 300 MPa for "S" and minimum value of 0, 3 for "m". Bitumen which fulfills these requirements criteria will be less stiff and able to relax thermal stress build-up at low temperature [2].

This paper shows the results obtained at BBR on 60/80 and 80/100 penetration grade bitumen samples coming from two different refineries in Romania. It is also presented a correlation between the Fraass breaking point's value (which is sometime a contested indicator and cannot be correctly correlated with the pavement's behavior [3]) and TS=300MPa, T_m=0,3, temperatures determined by interpolation of the curve plotting log S(60s) and log m (60s) as function log temperature [4].

2. MATERIALS AND PROCEDURES

2.1 Materials

Samples of Romanian bitumen RP and RA with 60/80 and 80/100 penetration grade obtained from two different refineries were studied. The bitumens were studied in original state and SBS polymer modified. For the modification there were used the SBS polymer with characteristics presented in table 1.

SBS modified bitumen's were prepared at 180°C, with an shear mixer, with 2000 rot/min. the rotation rate, 2 hours blending time, using 4% and 5% SBS polymer.

Table 1: The SBS polymer characteristics

Crt. No.	Characteristic	U.M.	CAROM TL 30
1.	Chain shape	-	linear
2.	Styrene content	%	30 ± 2
3.	Volatiles	%	0,7

2.2 Test Methods

Fraass breaking test were determined in accord with Romanian STAS 113/1974, using the PETROTEST equipment.

BBR test were determined in accord with SHRP specification, AASHTO Designation: TP1, at different temperatures

(-24, -18, -12 and -6°C for RA bitumen and -30, -24, -18°C for RP bitumen), using the equipment BBR, from ATS.



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3. RESULTS AND DISCUSSIONS

The results obtained for RP bitumen are shown in the no. 2 and no.4 tables.

This bitumen has low values for Fraass Breaking Point. The Creep Stiffness and m -value, obtained for -24°C and -30°C testing temperature, classify this bitumen in PG: -34. Isomodule temperature $T_{S=300\text{ MPa}}$ is lower than Fraass Breaking Point and higher than $T_{m=0.3}$.

Table 2: RP and RA bitumen characteristics

Bitumen	Characteristics					
	Penetration at 25°C , dmm	Softening point, $^{\circ}\text{C}$	Fraass breaking point, $^{\circ}\text{C}$	$T_{S=300\text{ MPa}}$ $^{\circ}\text{C}$	$T_{m=0.3}$ $^{\circ}\text{C}$	PG
RP1	60,5	49,7	-23,7	-28,3	-26,4	64-34
RP2	64,5	48,2	-23,7	-29	-30,5	64-34
RP3	70,2	46	-23	-27,7	-33,2	64-34
RP4	80,6	45	-24	-28,3	-29,3	58-34
RP5	84	46	-21	-28,7	-30,4	58-34
RA1	63,4	48,7	-16	-13,2	-8,2	58-16
RA2	60	47,2	-15,7	-19,3	-21,3	64-28
RA3	61	44,7	-15	-17,5	-25,8	58-22
RA4	80,7	43,8	-15,1	-15,24	-11,6	52-16
RA5	102,3	44,5	-17	-18,5	-	58-28



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The results obtained for RA bitumen are shown in the no. 2 and no.4 tables.

This bitumen has a variable behavior at low temperature. The Fraass Breaking Point values are in $-16^{\circ}\text{C} \pm 1^{\circ}\text{C}$ domain; the Creep Stiffness and m-value obtained for testing temperature, classify this bitumen in PG: -16, -22, -28 domain.

The results shown in the no. 3 table was obtained for the SBS polymer modified bitumen. The modification with polymer improved the Fraass Breaking Point for RP 5 and RA 3 bitumen. After modification, the RP bitumen performance grade remains the same (PG:-34), but the RA bitumen performance grade was improved (from PG: -22 to PG: -28).

Table 3: SBS modified bitumen's characteristics

Bitumen	Characteristics					
	Penetration at 25°C , dmm	Softening point, $^{\circ}\text{C}$	Fraass breaking point, $^{\circ}\text{C}$	$T_{S=300\text{MPa}}$, $^{\circ}\text{C}$	$T_{m=0,3}$, $^{\circ}\text{C}$	PG
RP3+4%SBS	38	58,5	-24	-29,2	-35,4	76-34
RP3+5%SBS	33	64,4	-24	-29,6	-33,2	76-34
RP5+4%SBS	51,3	58,5	-24	-28,8	-30,7	76-34
RA3+4%SBS	45,6	50	-18	-19	-25,8	70-28

Table 4: S and m SHRP parameters for original and SBS modified bitumen

Bitumen	Temperature $^{\circ}\text{C}$ and SHRP parameters				
	-6 S/m	-12 S/m	-18 S/m	-24 S/m	-30 S/m
RP1	-	-	81,2/0,357	182/0,322	373/0,287
RP2	-	-	124,5/0,385	225,2/0,355	320/0,302
RP3	-	-	79,2/0,392	180,6/0,372	378/0,336
RP3+4%SBS	-	-	50,8/0,390	179,6/0,367	342,8/0,340
RP3+5%SBS	-	-	50,8/0,390	121,2/0,364	322,6/0,332



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RP4			102/0,370	161,2/0,340	387,2/0,294
RP5	-	-	116,2/0,364	169/0,331	352/0,302
RP5+4%SBS	-	-	120/0,380	168/0,328	330/0,302
RA1	108,3/ 0,315	219,8/ 0,278	369,5/0,238	-	-
RA2	-	-	249,8/0,423	474,5/0,281	-
RA3	-	174/0, 378	317/0,340	458/0,312	-
RA3+4%SBS	-	169/0, 345	279,6/0,320	432/0,308	-
RA4	101,2/ 0,325	193,7/ 0,295	419,6/0,245	-	-

4. CONCLUSIONS

Romanian bitumen studied has a varied behavior at low- temperatures.

RP bitumen presents a better low temperature behavior than RA bitumen, having lower values for Fraass Breaking Point and Creep Stiffness, S. The PG for 60/80 and 80/100 penetration grade RP bitumen is PG: -34. The SHRP limiting temperature $T_{S=300 \text{ MPa}}$ is higher than $T_{m=0,3}$ and lower than Fraass Breaking Point.

RA bitumen presents a not so good behavior at low temperature, having a higher stiffness. The PG for 60/80 and 80/100 penetration grade RA bitumen is situated in -16;-22;-28 domain. Between $T_{S=300 \text{ MPa}}$, $T_{m=0,3}$ and Fraass Breaking Point there cannot be a correspondence.

Polymer modification improves the stiffness of studied bitumen (see S value in no. 4 table). After modification the PG grade for RP bitumen remains PG: -34 and for RA bitumen is improved from PG:-16 to -28. The improved stiffness parameters should lead to increased resistance of asphalt to thermal cracking in service period.

For both bitumen the $T_{S=300 \text{ MPa}}$ is lower than testing temperature for which $S=\max$. 300 MPa, that indicates that the 6°C steps between testing temperatures of the SHRP program are too big, smaller steps being necessary.

As in Romania the minimum pavement surface temperature is between -9°C and -30°C [5], depending on the area, bitumen having the proper PG must be used for each area.



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New non-destructive diagnostic method of bridges

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Abstract

Currently, on the base of foreign experience the Bridge Management System of the Czech Republic is created and progressively implemented. In connection with this process the requirements for non-destructive testing realized directly during the bridge structure inspections are on the increase.

In the past it was sufficient to realize only visual examination of defects. Now the prognosis of a future behaviour of the structure and determination of a residual life-time are required. The new bridges are more frequently equipped with monitoring facilities including data acquisition systems. As a part of the bridge inspection is commonly used carbonation depth survey, content of chloride and extent of reinforcement corrosion. The most frequent methods for determination of corrosion extend are ultrasound, sonar, infra-red camera, radar, electric potential measurement, radiography, vibration analysis, etc.

Next potential methods, which can be used in this area are modal analysis and acoustic emission method. The application of these methods on bridges is at the beginning.

The Czech Ministry of transport supports research and development (R&D) projects dealing with these two promising methods.

The article is dealing with R&D project, which is focused on usage of acoustic emission method as a tool for non-destructive testing of bridge structures, with a view to an assessment of reinforcement corrosion.

The measurement realized on laboratory samples and bridge structure will be mentioned, including information about equipment and measurement technique.



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1. INTRODUCTION

Concrete and prestressed structures condition is affected by varied factors. One of the most negative factors is reinforcement corrosion. At present time, CDV - Transport Research Centre and Physical Department of Faculty of Civil Engineering at Brno University of Technology are dealing with development of a diagnostic method based on the principle of acoustic emission. This method should be used for structural defects monitoring of concrete and prestressed structures, especially bridges, where defects were caused by reinforcement corrosion.

2. ACOUSTIC EMISSION

Mechanical energy appears whenever any object or structure is stressed. The energy is emitted in the form of elastic waves. This phenomenon is generally called Acoustic Emission (AE). Normally operated bridges are affected by dynamic actions caused by transport, wind etc. That gives rise to the acoustic emission. The research is trying to find the characteristic frequencies ("unhealthy sound") that are generated by corroded reinforcement of bridges while they are stressed.

3. STATE OF THE ART

The research focused on usage of AE method in the field of testing of reinforcement corrosion and prestressed structures is currently in progress at some research centres all around the world [2]. It include mainly testing of laboratory samples or testing of reduced girders, which are placed on the laboratory premises.

Canadian company Pure technologies has patented monitoring technology called Sound Print, which is able detect and localize wire breaks of prestressed cables with the accuracy of 0,5 m. The system uses an array of sensors, which monitor a part or whole supporting structure of bridges and similar structures. These sensors are connected with 32 channels acquisition unites. Signals are treated on-line and presented at Web pages. The provider of this technology in Europe is the company Advitam [3].

At Polish Kielce university they are dealing with a development of diagnostic method for testing of bridges based on AE principle. Loading of structures is realized by the help of heavy lorries, statically or dynamically. AE signals are analyzed in time domain. They execute a zonal localization of areas of defects. To determine the condition of girders parts is used AE parameters analysis. On the base of these parameters they count other indicators called historic index and



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severity, whose combination indicates the degree of defects of individual parts of a structure, mainly girders [4].

The other possibility is to measure acoustic response during using of the bridge. At University of Edinburgh they realized in-situ long term monitoring of bridge condition with the view of detecting crack growth and determining position of the crack tips. They worked with time domain of the signal. The compared parameters were number of detected events (their hits) and their energy [5].

4. MEASURING EQUIPMENT

For the measurement purpose we have used four channel acquisition system containing of a efficient personal computer, 12-bit sampling card NI 6115, amplifiers AMP 22 and 31, preamplifiers PA 15 and broadband piezoelectrical sensors (up to 1 MHz). Recorded signals were processed by the composed CDV software and the results were presented by the help of NI Diadem software. Connection diagram for one channel of the measuring system is shown in figure 1. The basic parameters, which are count from the time domain of the signal are presented in figure 2. The other parameters are energy, root mean square, average signal level, average frequency, etc.

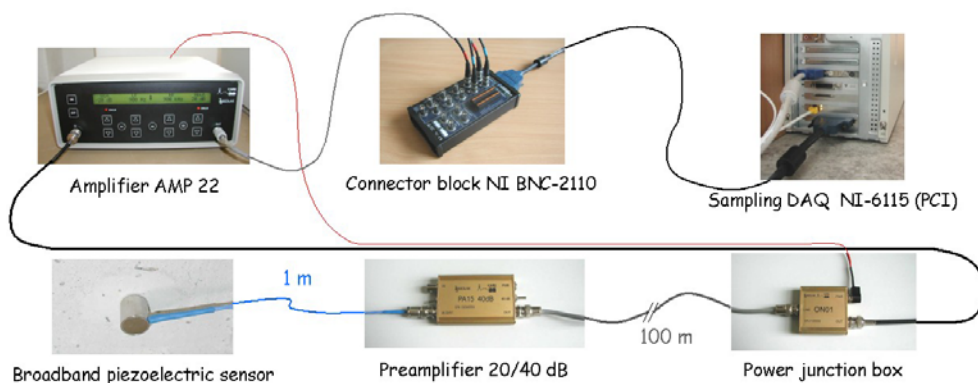


Fig. 1: Connection diagram for one channel of the measuring system

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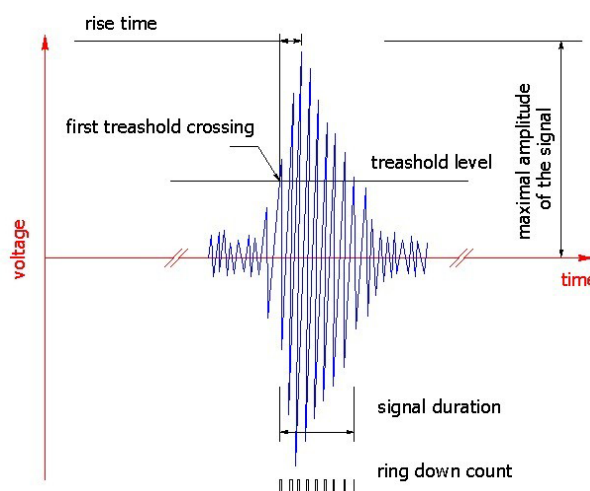


Fig. 2: Basic AE parameters counted from a time domain of the signal

5. OWN RESEARCH

The aim of our research is to propose methodology for preparation and realization of measurement of reinforcement defects of concrete and prestressed structures, with a use of AE method. One-time measurements will be carried out with a help of mobile equipment. The proposed measurement system is supposed to allow repeated measurements of more structures because it is not fixed to one construction for a longer period of time. The results and conclusions will form a base for the proposal of monitoring, repair and maintenance system of concrete road bridges.

6. LABORATORY MEASUREMENTS

Laboratory measurements were aimed to study an acoustic signal with the reinforcement corrosion correlation. The response signal to actuating pulse and AE signals recorded during the time when the samples were exposed to bending tension were analyzed.

In the first phase, the correlation of signal frequency spectra (response to actuating pulse on a reinforcement surface) for both corroded and partly corroded rebar was studied. There was an apparent shift of marked frequency components into lower frequency range in the case of partly corroded reinforcement.



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In the second phase, the samples exposed to accelerated corrosion were repeatedly monitored. The response of these samples on the actuated pulse was processed again. The response was recorded simultaneously on the reinforcement and on the concrete surface of the sample. With increasing corrosion, in the frequency spectrum marked frequency components shift into lower frequency areas, see figure 3.

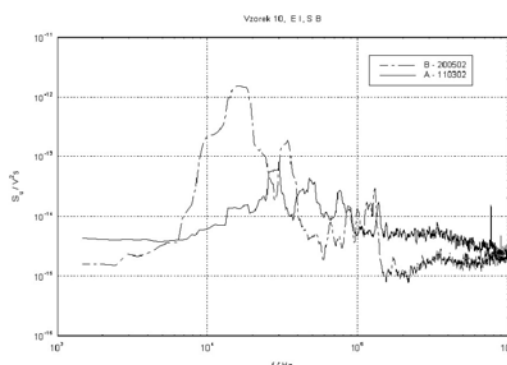


Fig. 3: Frequency spectra comparison



Fig. 4: Bending tension test

In the third phase, two sets of reinforced beams were monitored. One set aged in laboratory conditions while the other in an aggressive corrosive environment. Tested beams were repeatedly exposed to bending tensions according to European Standard EN 12390-5, see figure 4. Frequency spectra of the acoustic emission and the pulse frequency rate were processed.

The laboratory measurements proved correlation of changes in frequency spectra with structural changes caused by reinforcement corrosion. Satisfactory correlation was reached especially in the case of monitoring the proceeding corrosion by repeated sample measurements.

6. MEASUREMENTS ON THE BRIDGE

After verification of the possibility to detect corrosion of in-built reinforcement in laboratory conditions we started measurements in situ.

During the reconstruction of 20-year old bridge: 7-012 Brandysek, I73 bridge beams (prestressed I-beams) were tested by AE method. The bridge consisted of three spans with 9 beams, 30 m long each. Consecutively, when the beams were demolished, a condition of prestressed cables and construction reinforcement were checked.



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6.1 Process of measurement

The bridge profile is shown in figure 5. Eighteen I 73 beams were measured with the AE method. Sensors were fixed at the ceiling of each beam in the middle of its length. AE signals were generated by the lorry travelling over a 15 cm high wooden chock. The chock was placed on the road surface exactly above the point of measurement. The measuring system was powered by a generator. The use of the platform is shown in figure 6, AE signals generated by the lorry travelling over the chock is shown in figure 7.

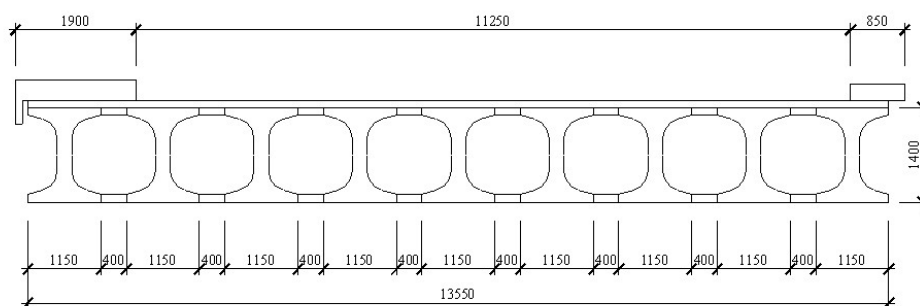


Fig. 5: Brandysek bridge profile

During the whole time the lorry travelling over the chock AE signal was continually recorded (approx. 15 seconds). Sampling frequency was selected at 1 MHz. Each beam was measured repeatedly, three times.



Fig. 6: Sensors placement process



Fig. 7: Lorry travelling over the chock

6.2 Beams demolition

Even before our measurement a decision was taken that the existing I73 beams would be removed and replaced with steel beams. The beams demolition was

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carried out on the spot with a help of a pneumatic hammer and hydraulic cutting shears. With the help of this equipment the concrete was broken, construction and prestressed reinforcement separated and taken away to be recycled. A visual examination was carried out both at the point of measurement and also along the whole length of the beam including the anchors and Sandrik steel pipes. The examination was aimed to all prestressed reinforcement consisting of 20-wire cables of 4.5 mm in diameter.

There was no significant effect of corrosion on the reinforcement section. For the evaluating purposes, the corrosive attack extent was divided into 4 groups (k1 up to k4).



Fig. 8: Four groups of corrosion

The reinforcement basically untouched by corrosion was put into the first group k1. The reinforcement close to the anchors, which was weakened by corrosion up to 0.5 mm and with initial signs of penetrating corrosion was placed into the fourth group k4, see figure 8.

6.3 The beams evaluation

FFT (Fast Fourier Transformation) was used to transform the acoustic signal from the time domain to the frequency spectrum.

The typical recorded signal is shown in figure 9. The arrows indicate events occurred when the lorry wheels hit the road surface. The arrow 1 corresponds to the front axle, the arrows 2 and 3 correspond to the wheels of the rear axle.

The time domain corresponding to the second and third wheel hitting were selected to analyze signals of individual beams. In figure 10, there is shown a time domain

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corresponding to hitting the second wheel of the rear axle to the road surface. Figure 11 represents its frequency spectrum.

There were found no significant differences when all frequency spectra were compared, in a range between 1 kHz and 500 kHz. In the scope of performed measurements, no frequency was found that would indicate some significant construction defect caused by the reinforcement corrosion. That corresponds to the visual examination of the reinforcement at the points of measurement. It proved that both the prestressed and the construction reinforcement were in suitable condition concerning to the corrosion.

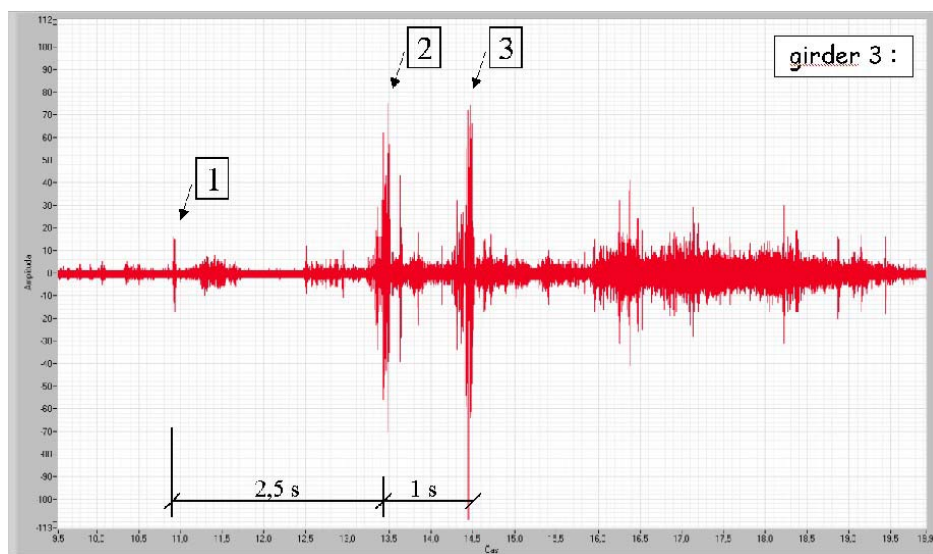


Fig. 9: Whole signal in time domain

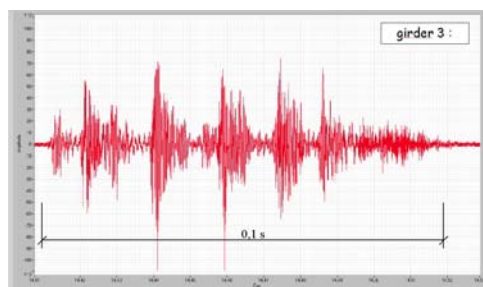


Fig. 10: Wheel 2 - time domain

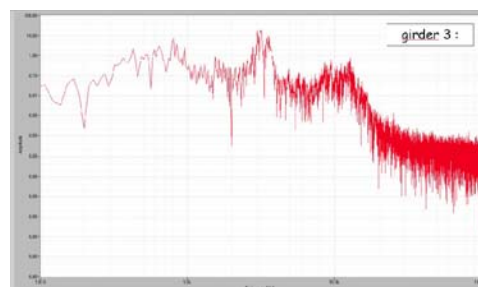


Fig. 11: Wheel 2 – frequency spectrum



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7. CONCLUSION

The significant advantage of the AE method is the fact that it indicates the unstable and dangerous defects, which are active at the given structure stress. In comparison with the other non-destructive diagnostic methods AE method can give global information about the examined object condition. According to the AE measurement results, it is possible to aim a diagnostic checking to those points where the emission sources were detected preferentially. Thus the AE method becomes a useful supplement to the common diagnostic methods.

Acknowledgements

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Etude des effets de saponification et de dégradation dans un recouvrement composé de petits éléments de pavage

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Summary

Dans le cadre de l'étude consacrée aux causes d'affaissement de recouvrements composés de petits éléments, maintes fois constatés sur site, le Laboratoire d'étude des matériaux a effectué des essais dynamiques ayant pour objet des revêtements en pavés. Les dommages sont fréquents sur les axes chargés, éventuellement en combinaison avec une charge lourde et dynamique du véhicule, ainsi que dans des endroits accueillant un trafic lourd, tels les récentes traversées de communes. Ces phénomènes de dommage sont également perceptibles autour des voies combinées pour les trams et les bus, ainsi qu'à hauteur des arrêts de bus. Les essais en laboratoire avaient comme objectif de simuler un certain nombre de situations critiques potentiellement comparables aux situations sur site et d'observer le comportement du lit et des éléments en de pareilles circonstances.

Afin de fonder les observations expérimentales par la théorie, un certain nombre d'essais et de situations de mise en charge furent numériquement simulées sur base de calculs analytiques. Cette approche théorique permet de proposer un certain nombre de formules pour la détermination de la charge maximale.

L'article présent traite uniquement de la partie expérimentale. La partie analytique fait l'objet d'une autre contribution.

1. INTRODUCTION

Le Cahier des charges type 250 pour la construction routière prévoit pour la pose du revêtement de routes édifiées en pavés en béton les 4 options suivantes en matière de matériaux : un lit de sable, un mélange de sable de concassage et de gravier 0/4 ou 0/7, un mélange de sable ternaie, du ciment-sable ou du mortier.

Dans cette optique et en première instance, des essais de simulation furent conduits sur un revêtement composé d'éléments en béton rectangulaires posé sur une couche de pose en sable. Ils visaient à simuler un certain nombre d'effets – affaissement – observés sur site. Ces simulations étaient toutes basées sur un modèle de laboratoire, établi selon la procédure sous-mentionnée.



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Dans sa configuration, l'essai est composé d'un cadre d'essai posé sur un plancher d'essai, d'un vérin servo-hydraulique et d'un capteur optique au laser placé à distance. Le plancher d'essai est entièrement antivibratoire. Étant donné que l'étude porte sur le comportement de la couche de pose et des pavés, indépendamment du comportement de la fondation et/ou de la sous-fondation, le modèle réduit est construit sur une dalle en béton rigide. Le cadre d'essai est muni d'un vérin servo-hydraulique, produisant une poussée maximale de 100 mm et pouvant générer une force de traction et de compression dynamique de 250 kN à maximum 5Hz.

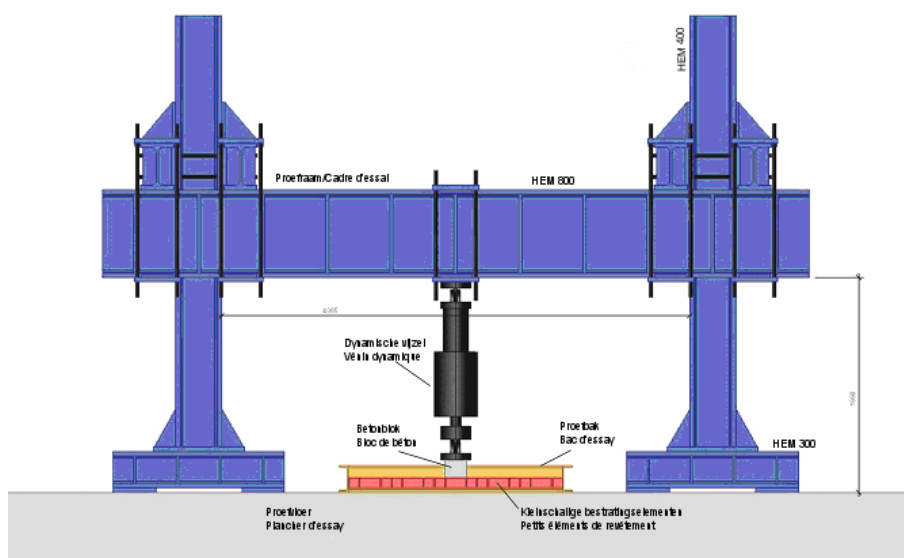


Figure 1: présentation schématique de l'essai

Le plancher d'essai accueille un bac d'essai en acier (dimensions 200 x 200 x 22 cm), centré sous le vérin dynamique. Le bord du bac en acier est fait de profils UPN 220. Une couche de pose est apposée dans le bac. Si la couche de pose dispose d'un lit de sable, l'épaisseur nominale après compaction s'élève à 3 cm. Si le lit est composé de gravier, l'épaisseur nominale est de 4 cm, après compaction. Ensuite, le lit est égalisé et les pavés disposés. Les pavés en béton sont placés en appareillage en épi. Les jointoiements sont faits avec du sable blanc 0/2. Le revêtement est fixé à l'aide d'une plaque vibrante. Ensuite, un bloc en béton (20x20x20 cm) est placé au milieu du lit d'essai et le vérin est aligné. La couche de pose et le sable de jointoiement sont saturés d'eau. L'essai est prêt à débuter.

En vue de simuler la charge dynamique, initiée par la roue d'un camion, une force sinusoïdale variant entre 25kN et 75kN à 1Hz est transmise, à l'aide d'un vérin



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dynamique, sur le revêtement, par l'intermédiaire d'un bloc de béton entre pied, vérin et pavé.



Figure 2: photo essai.

2. MESURES

Outre l'exécution des mesures, conformément aux descriptions reprises sous cette rubrique, une expertise visuelle est effectuée. Les affaissements observés sur site sont constatés dans le laboratoire. La photo 4, par exemple, montre comment le matériau de jointoiement est comprimé et poussé vers la surface. De plus, des cavités prennent forme dans les joints.

L'étude a démontré que les affaissements trouvent leur origine dans l'apparition du phénomène de saponification ainsi que dans la dégradation des granulats de la couche de pose.

La saponification est l'état de suspension du matériau granulaire du lit de pose saturé d'eau, occasionné entre autres par des vibrations et par le déplacement des fines particules qui en résulte. Les fines particules du lit de pose sont expulsées avec

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l'eau au travers des joints pour se retrouver à la surface. Les cavités qui en résultent mènent, en raison des vibrations continues et de la charge due au trafic, à une recompaction du lit de pose.



Figure 3: Suite à la dégradation, à la saponification (et au pumping), des affaissements font leur apparition, parfois sur l'épaisseur totale de la couche de pose.

L'effet produit sur le revêtement par une charge lourde et dynamique, et qui provoque le concassage du matériau granulaire dans le lit de pose et donc l'apparition de très fines particules s'appelle la dégradation. Ce phénomène a comme conséquence qu'une quantité importante de matériau fin se forme dans la couche de pose, ce qui la rend plus sensible au mécanisme de saponification.



Figure 4: jointoiement comprimé (en labo).

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Dans le cas de dommages réels, une troisième cause entre en ligne de compte : l'effet de pumping. Toutefois, compte tenu de la configuration actuelle de l'essai, cet aspect ne peut être simulé. Afin de faire en sorte que les dommages simulés correspondent encore mieux à la réalité, une étude est actuellement en cours, consacrée à une configuration qui simulerait également l'effet de pumping.

L'exécution des ces mesures est effectuée selon la procédure suivante :

La compression du bloc et le signal de la force sont enregistrés de façon continue par un capteur optique au laser placé à distance. La flexion du cadre n'a pas d'influence sur la mesure, étant donné que celle-ci est prise directement sur le bloc en béton et que le capteur optique au laser a comme référence le plancher d'essai.

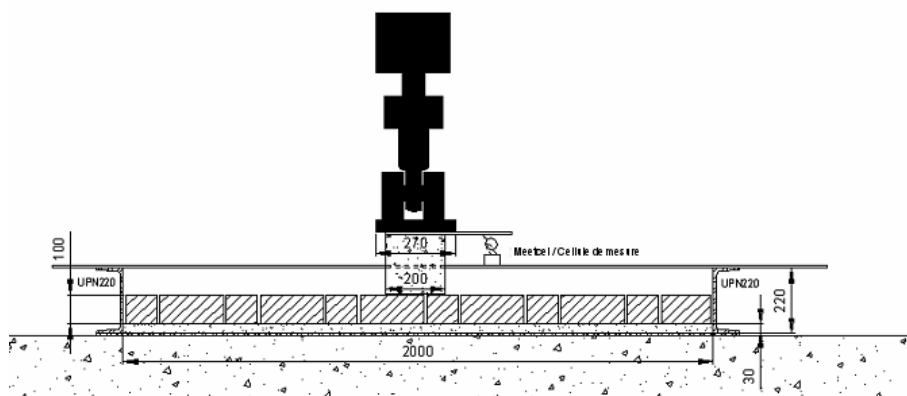


Figure 5: détail bac d'essai

La compression des éléments est minutieusement enregistrée dans le temps avec une précision de 1/100 mm. Les signaux de la force et de l'affaissement sont traités statistiquement et en temps réel par Virtual Instrument (LabVIEW) et retranscrits de façon continue sur une feuille de calcul.

Après l'essai, les éléments sont enlevés et des échantillons sont pris de la couche de pose, sous le pavé et sous le joint. Une étude de la composition granulométrique du sable de jointoiement et du matériau qui a été expulsé vers la surface est effectuée.

L'échantillonnage de la couche de pose est effectué à l'aide d'un anneau en acier, tel que représenté ci-dessous (figure et photo).

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Figure 6: photo anneau de mesure

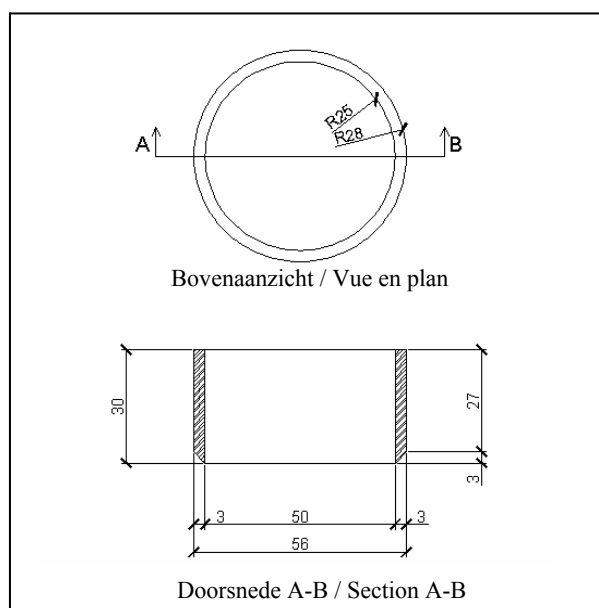


Figure 7: dessin anneau de mesure

La granulométrie de la couche de pose est déterminée via une étude granulométrique, par le passage au tamis et par une comparaison avec la granulométrie d'origine.

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3. RESULTATS DES ESSAIS

Lors de la présentation des résultats, nous nous attarderons en première instance sur la compression des éléments de recouvrement, et en deuxième instance sur le comportement granulométrique de la couche de pose sous l'effet d'une force dynamique.

Nous illustrons le comportement de compression à l'aide d'essais visant à comparer le porphyre 1/6,3 et le sable 0/5.

L'utilisation d'une couche de pose avec du sable 0/5 nous montre que les affaissements augmentent en fonction des cycles de charge (voir graphique figure 8). Le diagramme 8 et le tableau 9 nous montrent un affaissement de ± 6 mm, à partir du 120.000^{ième} cycle.

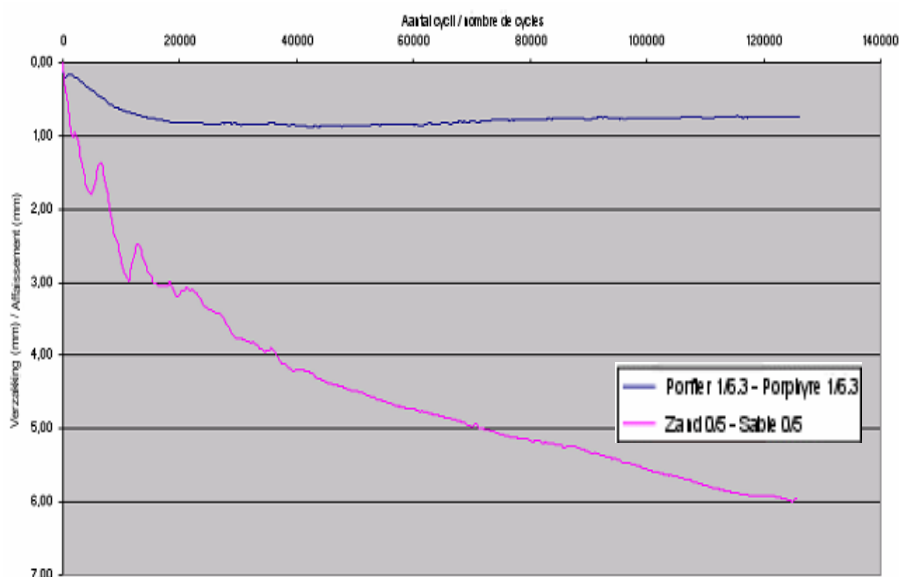


Figure 8: diagramme de compression

Le graphique repris dans la figure 10 représente la situation d'une couche de pose avec du sable 0/5. Le graphique compare la granularité avant et après le déroulement des cycles de charge. Il concerne un échantillon pris sous le joint, près de l'endroit soumis à la charge.



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Doorlopen cycli Déroulement des cycles x 1000	Gemiddelde kracht Force moyenne kN	Tijd (uur) Temps (heure)	Zakking Affaissement mm
0	46.08	0.0	0
15	45.81	4.2	2.822
28	45.85	7.8	3.666
42	45.87	11.7	4.291
56	45.60	15.6	4.702
70	45.46	19.4	4.994
84	45.66	23.3	5.247
99	45.82	27.5	5.575
113	45.84	31.4	5.872
124	45.89	34.4	5.963

Figure 9: résultats des mesures pour une couche de pose avec du sable 0/5

Nous constatons (figure 10) que la quantité de matériau destinée au lit de pose ayant un passage au tamis de 0,63 mm et 0,32 mm (avant les cycles de charge) diminue et évolue vers un passage au tamis de 0,16 mm. Une partie du matériau fin est éjectée de la couche de pose au travers du joint. Le matériau le plus fin (0,08) a disparu. De ce fait, nous obtenons un matériau plus fin à la fin de l'essai. L'apparition de ces fines particules s'explique par la dégradation du sable. L'apparition de la dégradation du sable 0/5 est également démontrée par le tableau ci-dessous (figure 11) ainsi que par la courbe granulométrique (figure 12).

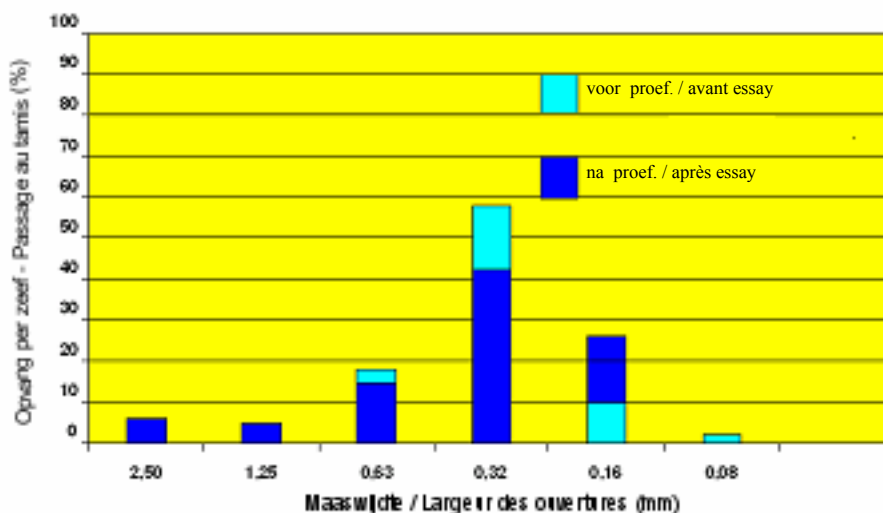


Figure 10: tranches granulométriques sable 0/5



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		<0.08	0.08- 0.125	0.125- 0.25	0.25- 0.5	0.5-1	1-2	2-4	4-6.3	>6.3
Avant essai		0.05	0.25	5.72	46.01	33.22	6.02	4.25	3.24	1.22
Après essai										
Pavé en terre cuite	OK	0.26	0.56	14.11	48.55	20.65	7.39	4.54	3.17	0.73
	OV	0.26	0.56	14.11	48.55	20.70	7.17	4.42	3.08	1.16
Pavé en béton	OK	0.12	0.55	13.28	48.88	20.74	7.56	4.80	3.00	1.08
	OV	0.08	0.40	13.56	47.33	20.17	7.56	5.27	4.02	1.61

Figure 11: résultats des mesures sable 0/5.

Le graphique 8, enregistré lors de l'essai consacré à la couche de pose avec du porphyre 1/6,3, montre que la compression maximale est atteinte quasi immédiatement après l'application de la charge dynamique. Cet affaissement ne s'élève qu'à 0,8 mm. Aucun affaissement supplémentaire n'est enregistré pendant la suite de l'essai.

Le tableau 11 représente la moyenne des valeurs enregistrées lors de 10 mesures. Le tableau montre que la dégradation est la plus grande avec une tranche granulométrique de 0,5 – 1. Il montre également qu'après le passage des cycles de charge, le pourcentage de fines augmente considérablement, jusqu'à 300 %.

4. CONCLUSIONS

Le Laboratoire d'étude des matériaux a entrepris un projet de simulation d'affaissements observés sur site pour des revêtements composés de petits éléments de pavage, posés sur une couche de pose de sable 0/5 couramment utilisé. Les phénomènes de dégradation et de saponification ont été démontrés. La dégradation engendre une quantité importante de matériau fin, ce qui renforce la saponification et augmente l'affaissement qui en est la conséquence. Une observation a permis de constater la poussée des fines au travers des joints vers la surface.

Les résultats des essais montrent qu'en cas d'utilisation de concassé de porphyre comme couche de pose, la dégradation et les affaissements sont quasi inexistantes.

Ces résultats ont initié les études suivantes.

D'une part, une étude systématique de la dégradation et de la saponification pour toutes les couches de pose décrites dans le *Typebestek 250 voor de wegenbouw*. La vulnérabilité face à la dégradation de ces couches de pose y est étudiée par une approche microscopique et minéralogique, par le biais d'une étude SEM et EDX, une granulométrie au laser, une diffraction aux rayons X et des essais optiques.



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D'autre part, en raison des excellents résultats du concassé de porphyre comme couche de pose, la seconde étude concerne la mise en place d'une optimisation de la granulométrie.



Technology Research in Transport Infrastructure

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INTRODUCTION

Due to the continuing decrease in the amount of material and energy sources during the recent years, as well as the increase of their prices, there has been more emphasis on the reliability, lifespan and safety of transport infrastructure constructions, while minimising their negative effects on the living environment. Therefore the Transport Research Centre (Centrum dopravního výzkumu - CDV), specifically the Infrastructure Department, has been trying to help this trend by a research in the field of geotechnics, technology of concrete and non-destructive structures testing.

1. GEOTECHNICS

In the field of geotechnics the research activity concentrates on projects linked to the relationship between geotechnical quantities and geosynthetics influence on increase of soft soil bearing capacity. In order to make the geotechnical research more effective, a Geotechnical Laboratory Testing Field (GLTF) was built in the year 2001.

1.1. Geotechnical Laboratory Testing Field (GLTF)

The GLTF is a laboratory tool, which allows the measurement, in a laboratory, of some of the geotechnical quantities usually measured in the field (such as a plate test, dynamic loading test, penetration test, etc.) on various soils and soil layers for different compaction rate and water regimes. Unquestionable advantage of GLTF is the possibility to carry out all kinds of geotechnical tests on constructions of real scale while still in the laboratory-protected conditions.

The GLTF, Figure 1 left, consists of concrete pit split by removable dividers into separated measuring (testing) spaces and a watering/dewatering drain channel separated by removable dividers too. There is a drain layer placed on the bottom of each measuring space closed off by a grate with a geotextile drainage filter. Both the concrete pit and the drain channel are interconnected at their bottoms. A moveable frame can be slid in a longitudinal direction along guide rails fastened to the top of the pit. The moveable frame serves for mounting or supporting of



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measuring equipment (plate test, CBR in situ test equipment etc.) and can be locked in both horizontal and vertical senses during testing.

The GLTF has been recently equipped with a loaders for accelerated testing of soil and unbound layers, see Figure 1 right. The GLTF is becoming an accelerated loading testing equipment. Currently the geosynthetics behaviour under cyclic loading (simulation of traffic loading) is tested. There is also a plan for a research project focused on the accelerated testing of reinforced joins. The project should be aimed on tolerance findings of reinforcing dowels angular displace and durability of additionally placed dowels.

The GLTF description has been published [1,2] and is protected by the utility design [3].



Fig. 1 – Laboratory Geotechnical Testing Field (GLTF) left – general view with static plate test, right – equipment for cyclic loading

1.2 Correlation of California Bearing Ratio CBR and deformation modulus

Deformation modulus, especially its value detected by static loading test in the second loading cycle E_{v2} , is one of the most important parameters checked at the final subgrade, just after the compaction rate and moisture content of the soil. Deformation modulus is used for verifying deformation characteristics of final subgrades. In a number of European countries, e.g. in Germany, Austria, Czech republic, Slovakia, etc. there is a minimum value of this modulus specified by standards, which has to be reached.



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Predictability of the compliance with a specific minimum value of the deformation modulus is a crucial condition for the economy proposal for the earth works, as the real value of this modulus can be detected only after the earth works have been finished. The final subgrade, or the capping layer, then either meets or doesn't meet the given criteria. If the deformation modulus detected at the given deformation and moisture ratio is lower then required, the subgrade has to be usually remoulded, adjusted and then compacted again. It is obvious that this causes undesired extra expenses.

From the problem described above it can be seen that it is useful to know the expected deformation modulus of the subgrade already at the time of the proposal, given the specific soil type; or alternatively to know what sort of soil adjustment should be suggested so that the expected value of the deformation modulus is sufficient. As can be observed from the professional studies, one of the means for this prediction can be the correlation of the deformation modulus and the California Bearing Ratio (CBR). Unfortunately, in the literature available, no relation between the deformation modulus in the second load cycle and CBR specified at the same or optimum moisture content has been found.

Assumptions, methodology and evaluation from the research described here have been continuously publicised, e.g. [4, 5] (they are also available from the author of the English version). So it would be only superfluous to give here their detail description here, and moreover it would unproportionately excess the capacity of this article. However it should be state here that the tests have been carried out on real construction sites and in GLTF, on various soil types, on various compaction and moisture. The California Bearing Ratio *CBR* has been detected at intact samples, which were collected within a minimum distance from the compaction modulus testing place. Thus both of the correlated geotechnical quantities (*CBR* and E_{v2}) have been detected under the very same conditions (moisture, compaction ratio, etc.).

One of the solution output is table 1. This is in a certain modification also included in the draft revision proposal of the Technical Conditions of the Transport Ministry TP 77 – Road design whose elaborator is the Faculty of Civil Engineering, Brno University of Technology. Table 1 has been done by compiling the results of the CDV research (column E_{v2}) and the enclosures from the Czech Standard CSN 72 1002.



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Table 1 – Deformation Modulus of the second cycle $E_{\text{def},2}$ for various soil types

Serial No.	Soil type	Symbol	Fine particle content f [%]	California Bearing Ratio CBR [%]		Modulus E_{v2} [MPa]
				Optimum Moisture	95% saturation	
1	gravel silt	F1 MG	35 – 65	8 – 18	5 – 10	20 - 40
2	gravel clay	F2 CG	35 – 65	5 – 10	3 – 7	15 - 30
3	sandy silt I	F3 MS ₁	35 – 50	5 – 25	4 – 15	15 - 45
4	sandy silt II	F3 MS ₂	50 – 65	3 – 15	2 – 5	5 - 40
5	sandy clay I	F4 CS ₁	35 – 50	5 – 30	5 – 20	15 - 50
6	sandy clay II	F4 CS ₂	50 – 65	2 – 20	0 – 4	0 - 40
7	low plasticity silt	F5 ML	> 65	2 – 20	2 – 7	0 - 40
8	medium plasticity silt	F5 MI	> 65	2 – 15	1 – 6	0 - 40
9	low plasticity (lean) clay	F6 CL	> 65	3 – 20	1 – 8	5 - 40
10	medium plasticity clay	F6 CI	> 65	2 – 20	0 – 6	0 - 40
11	high plasticity silt	F7 MH	> 65	3 – 7	0 – 4	5 – 25
12	very high plasticity silt	F7 MV	> 65	2 – 6	0 – 3	0 – 20
13	extremely high plasticity silt	F7 ME	> 65	2 – 5	0 – 2	0 – 20
14	high plasticity clay	F8 CH	> 65	2 – 7	0 – 3	0 – 25
15	very high plasticity clay	F8 CV	> 65	1 – 7	0 – 3	0 – 25
16	extremely high plasticity clay	F8 CE	> 65	1 – 6	0 – 3	0 – 20
17	well-graded sand	S1 SW	< 5	-	-	-
18	poorly-graded sand	S2 SP	< 5	-	-	-
19	sand with fine soil additive	S3 S-F	5 – 15	8 – 70	6 – 25	20 – 65
20	silty sand	S4 SM	15 – 35	6 – 50	4 – 15	15 – 55
21	clayey sand	S5 SC	15 – 35	4 – 30	2 – 12	10 - 50
22	well-graded gravel	G1 GW	< 5	-	-	-
23	poorly-graded gravel	G2 GP	< 5	-	-	-
24	gravel with fine-soil additive	G3 G-F	5 – 15	20 – 90	6 – 60	35 - 65
25	silty gravel	G4 GM	15 – 35	10 – 60	4 – 40	25 - 60
26	clayey gravel	G5 GC	15 – 35	5 – 30	3 – 20	15 - 50



1.3 Study of the geosynthetics effect on the increase of the bearing capacity of subgrade

Geosynthetics (geotextiles, geogrids, geonets, geocells and geocomposites) are suggested as substances for improving the characteristics of materials of constructions used in transport civil engineering. Every geosynthetic should fulfil at least one or more of the following functions: filtration, separation, draining, protection, anti-erosive and reinforcing function. The last mentioned reinforcing function used for example in case of embankment construction when steeper slope of embankment can be designed is determined relatively well. While in the literature, especially in the company materials, one can often find information that by using geosynthetics one can be increased even the bearing capacity of soft soil, the problem has not been solved satisfactorily yet.

The research carried out at CDV concentrated especially on the study of the geosynthetics' effect on the increase of the bearing capacity soils. A number of validation tests have been carried out in GLTF recently. The specialists/professional public have been informed about the continuous results through journal and conference papers, for example see [6, 7]. The quoted publications discuss in detail the results of the surveys carried out. For this reason, it is described here the research resume only.

Presumptions and parameters

Measurements of the bearing capacity were done by modulus of deformation obtained from the second loading cycle of the static plate test, see Figure 1 left, according to two methods. The first method is widely used in Europe for highway subgrade evaluation and it is described some European standards, e.g. in DIN 18134 (German Standard) or CSN 72 1006, Appendix A (Czech Standard), and the resulting modulus is called E_{v2} . The second method used for railway subgrade evaluation is described in Czech Railway Standard S4, and the resulting modulus is called E_0 . Both methods vary mainly in the ways of loading, and there is also a small dissimilarity in the modulus of deformation calculation. However, for our purpose, it is possible to say that both methods are able to express the impact of geosynthetics on the bearing capacity in a similar way.

The GLTF was divided into 3 testing spaces for measurement and experiments to be performed according to the following conditions. A 70cm thick bed of loess, compacted layer by layer, simulating a soft-soil subgrade was placed on the drainage layer of all three testing spaces of the GLTF. The compaction of the soft soil was about 95 % Proctor Standard (PS) and its bearing capacity was set by moisture content on 5 MPa, 7 MPa and 15 MPa respectively.



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Selected geosynthetics were laid down in to two GLTF testing spaces and one testing space was kept without geosynthetics for comparison. After that, a crusher-run material was spread as a sub-base layer. It was placed in 15cm or 20cm thick layers, and compacted to at least $I_D = 0.85$, as measured. After measuring the modulus on the top of sub-base layer, an additional 10cm, 15cm, or 20cm thick sub-base layer was spread and the measurement was repeated.

Measurement and results

As indicated above, measurements were carried out in the GLTF, which had been divided into the three same size (3 m x 3 m) testing spaces. Two geosynthetics were measured in one step – one by one in each of two testing spaces and one testing space was kept without geosynthetics a for comparison. Measurement of moduli was carried out three times in each testing space according to both highway and railway standards mentioned above. The following tables display average values of both moduli measured on 15 cm or 20 cm level and on 30 or 40 cm level of sub-base.

Table 2 Measurement on Subgrade with Bearing Capacity of 5 MPa

Testing space	Geosynthetics	Layer thickness	Modulus E_0 [MPa]	Bearing capacity increase	Modulus E_{v2} [MPa]	Bearing capacity increase
I	welded geogrid	15 cm	11.38	1.22	11.38	1.13
		30 cm	23.65	1.07	22.06	1.13
II	non-woven geotextile	15 cm	9.08	no benefit	9.94	no benefit
		30 cm	22.74	no benefit	17.43	no benefit
III	unreinforced (referential)	15 cm	11.13	1.00	10.11	1.00
		30 cm	22.21	1.00	18.18	1.00

Table 3 Measurement on Subgrade with Bearing Capacity of 7 MPa

Testing space	Geosynthetics	Layer thickness	Modulus E_0 [MPa]	Bearing capacity increase	Modulus E_{v2} [MPa]	Bearing capacity increase
I	unreinforced (reference)	20 cm	17.90	1.00	unexecuted	N/A
		40 cm	69.16	1.00	53.66	1.00
II	woven geotextile	20 cm	23.23	1.30	unexecuted	N/A
		40 cm	63.76	no benefit	56.51	1.05
III	rigid Geogrid A	20 cm	24.89	1.39	unexecuted	N/A
		40 cm	62.08	no benefit	55.41	no benefit



Table 4 Measurement on Subgrade with Bearing Capacity of 15 MPa – 1st Series

Testing space	Geosynthetics	Layer thickness	Modulus E_0 [MPa]	Bearing capacity increase	Modulus E_{v2} [MPa]	Bearing capacity increase
I	Woven geotextile	20 cm	32.35	no benefit	25.17	no benefit
		30 cm	43.75	no benefit	33.28	no benefit
II	rigid geogrid A	20 cm	31.90	no benefit	29.79	no benefit
		30 cm	47.06	no benefit	34.06	no benefit
III	unreinforced (reference)	20 cm	31.74	1.00	28.43	1.00
		30 cm	47.35	1.00	34.20	1.00

Table 5 Measurement on Subgrade with Bearing Capacity of 15 MPa – 2nd Series

Testing space	Geosynthetics	Layer thickness	Modulus E_0 [MPa]	Bearing capacity increase	Modulus E_{v2} [MPa]	Bearing capacity increase
I	rigid geogrid B	20 cm	32.98	no benefit	25.94	no benefit
		30 cm	46.48	no benefit	35.19	no benefit
II	welded geogrid	20 cm	32.80	no benefit	27.87	no benefit
		30 cm	47.38	no benefit	35.54	no benefit
III	unreinforced (reference)	20 cm	38.33	1.00	29.26	1.00
		30 cm	52.48	1.00	37.74	1.00

Table 6 Measurement on Subgrade with Bearing Capacity of 15 MPa – 3rd Series

Testing space	Geosynthetics	Layer thickness	Modulus E_0 [MPa]	Bearing capacity increase	Modulus E_{v2} [MPa]	Bearing capacity increase
I	flexible geogrid A	20 cm	31,16	no benefit	27,18	no benefit
		30 cm	47,92	no benefit	34,82	no benefit
II	flexible geogrid B	20 cm	29,99	no benefit	29,79	no benefit
		30 cm	42,26	no benefit	37,06	no benefit
III	unreinforced (reference)	20 cm	33,36	1.00	28,43	1.00
		30 cm	49,95	1.00	39,89	1.00

Various kinds of woven and non-woven geotextiles, and welded, flexible and rigid geogrids were used for the experiment. All of them are products of well-known producers and are certified for highway and railway usage.

Discussion of results

Table 2 displays measurement results for welded geogrid and non-woven geotextile on a very weak subgrade of 5 MPa of bearing capacity. Measured data shows that there is no benefit from non-woven geotextile on bearing capacity increase. However, welded geogrid demonstrated 22 % and 13 % (railway and highway



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modulus measurement methodology) bearing capacity increase on a 15cm thick sub-base layer in comparison with unreinforced structure, and 7 % and 13 % bearing capacity increase on a 30cm thick sub-base layer.

Table 3 displays measurement results of woven geotextile and rigid geogrid A on a very weak subgrade of 7 MPa of bearing capacity. Measured data shows that woven geotextile yields bearing capacity increases of up to 30 %, and rigid geogrid A up to 39 % on a 20cm thick sub-base layer; however there is no significant bearing capacity increase on a 40cm thick sub-base layer.

Tables 4, 5 and 6 display measurement results obtained for woven geotextile, rigid geogrid A, rigid geogrid B, welded geogrid, flexible geogrid A and flexible geogrid B placed on weak subgrade of 15 MPa of bearing capacity. All results show that there is no significant bearing capacity increase on a 20cm and 30cm thick sub-base layer either.

Outcome

The performed experiments imply that the influence of selected geosynthetics on the bearing capacity increase of weak subgrade is very limited. Measurement shows geosynthetics are able to increase the bearing capacity of very weak soil (a subgrade with bearing capacity expressed by deformation modulus of 5 MPa or 7 MPa), namely in relation to a relatively thin sub-base layer – up to 20 cm. As such a weak subgrade is not useful for highway or railway foundation, it would be useful only for the temporary subgrade improvement of roads on such a weak subgrade. Improvement of weak soil (bearing capacity 15 MPa) by geosynthetics was not shown, in contradiction to the claims in the trade publications from the geosynthetic producers.

2. SELF-COMPACTING CONCRETE (SCC)

A very important operation carried out in case of monolithic concrete constructions and during the production of prefabricated elements is the compaction of the concrete mixture. Compaction is there to ensure both the required density of the concrete, its homogeneity, and also infilling of all the specified room with the concrete mixture, so that the synergism of the concrete with the reinforcement is ensured too. A number of compaction methods and compacting devices can be used for this purpose achievement. Especially nowadays when more and more subtle constructions with high reinforcement degree are being designed, the execution of the compaction process is becoming more demanding, as it is difficult to ensure optimum compaction of all parts of the future construction or of the prefabricated element. This can then cause cavities, gravel nests or other non-uniformity signs or anisotropy, which may degrade the visual effect, allow



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reinforcement corrosion or endanger statistic or possibly even dynamic characteristics of the whole construction. A modern solution to the problem described is using such a concrete mixture that will fill in the entire volume of the construction, thanks to its own gravity effect, and at the same time completely coat up the reinforcement - all this without any need of a compaction operation. The material of such characteristics is called the Self-Compaction Concrete (SCC). But together with the SCC technology being introduced to the civil engineering practice a number of other problems that didn't used to be so important in the past when using traditional concrete technologies become now topical. Mixtures for self-compaction concrete must show high level of mobility at appropriate viscosity (a mixture is supposed to fill in the entire designated space spontaneously), there can be no segregation of the coarse components in the mixtures caused by the effects of the components mobility or by blocking the reinforcement, etc. However, compliance with these requirements often affects the fundamental concrete parameter, which is its strength.

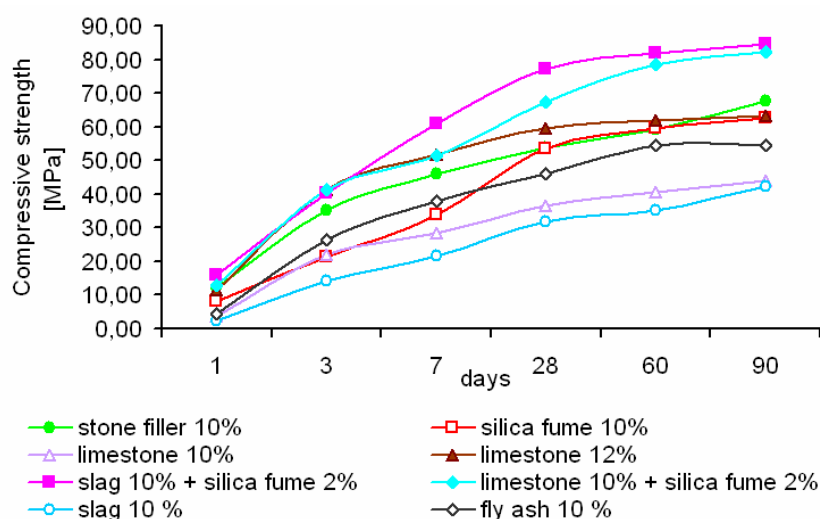


Fig. 2 – Development of the compression resistance increase of various SCC in relation to time

One of the means for reaching the required characteristics of the mixture is making use of the new generation surface-active substances, i.e. super-plasticizers adjusting the mixture mobility, and also by the means of higher volume of fine particles proportion in the filler, ensured by the addition of micro-fillers. Industrial by-products can be used as the micro-fillers (e.g. silica fume, fly ash, finely grained slag or limestone, stone fillers, etc.). The SCC technology is therefore important



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also from the view of utilising waste materials and thus contributing to the environment protection.

The SCC technology development has been known since the last decade of the 20th century, so it is a rather new technology. However, CDV infrastructure laboratories have been carrying out surveys concentrated on monitoring the effects of concrete mixture composition on the characteristics of self-compaction concrete already since the year 2000.

Our tests have proved significant behavioural changes of concrete mixtures in relation to their type and volume of the used micro-filler. Similarly, the results of tests on the matured concrete prove a significant dependence of their mechanically-physical parameters on the formulation of the used concrete mixture, see for example the graph in fig. 2. The conclusions of some experimental tests have already been published [9, 10, 11]. Further tests are currently taking place and their results will be gradually announced to the specialists.

3. NON-DESTRUCTIVE TESTS OF BRIDGE CONSTRUCTIONS

The analysis of the central bridge registration on the roads of the CR shows that from the total number of 15 650 of road bridges only 5 823 conform or conditionally conform (i.e. almost don't conform), which is more than a third (37%). From the mentioned number further 1 360 bridges are dilapidated (in a state of disrepair). 19 of these bridges have their span bigger than 100 m, 97 of bridges have span 30 - 100 m, etc. Almost the same can be said about the conditions of bridges in other European countries.

Such poor bridge conditions are caused partly by the lack of financial means for their maintenance, but also by the absence of adequate, relatively quick and cheap monitoring method which would enable us to detect their defects in early stages, allowing us simple and financially not very demanding maintenance. One of such possible solutions could be a method based on the principle of acoustic emission (AE). Diagnostic methods using AE belong to the group of non-destructive passive methods and use gradual wave pulses. The signals of acoustic emissions accompany the dynamical processes in the material and then come through as gradual elastic wave motion. The source of such wave packages are sudden energy releases in the material. This process is followed by deformation, fracture or phase changes in the material.

CDV is, together with the Physics Institute of Faculty of Civil Engineering, Brno University of Technology, the solver of the grant of the Czech Ministry of Transport "Methodology of the reinforcement corrosion process determination of reinforced and prestressed structures". The aim of this project is to produce



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technical guide that will codify the acoustic emission (AE) method as a method for routine use in the bridge management system.

The survey began by a detail study of survey results of other prominent research centres. It was realised that the task given by the Ministry was with its approach to the point of issue entirely new and that now other research centre had ever specialised in such a project. So from this point of view, the survey is quite unique, on the border of basic research and applied survey. And even though the AE principle has been know for several years, it has never been quite verified whether the corrosion process in the reinforcement can come through in the frequency spectrum of the construction.

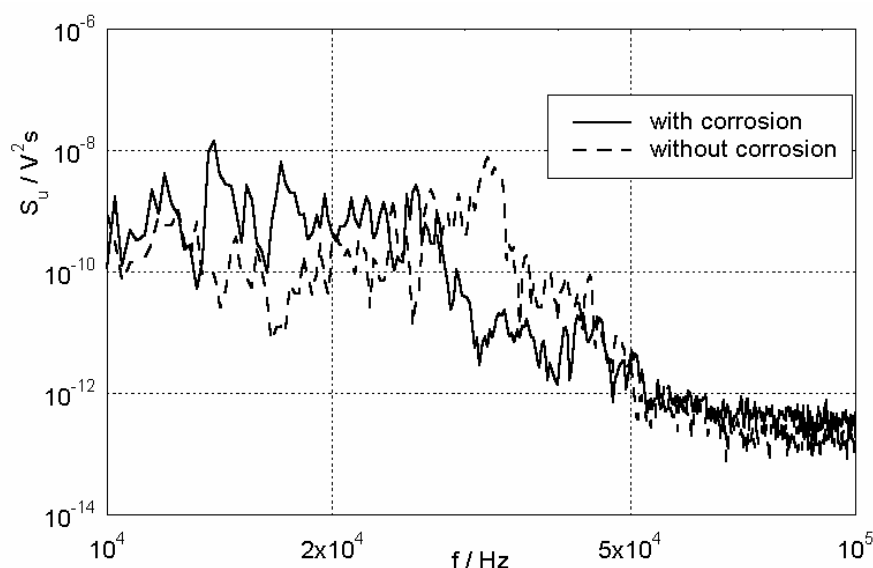


Fig. 3 – Comparison of spectra of supports with corroded and not corroded reinforcement

Another part of the survey was dedicated to finding a device that would be suitable for reading the AE signals both in laboratories and in real conditions. Firstly, a two-channel device was constructed which was later extended into a four-channel one. So now we can measure a signal read by four indicators placed at different parts of the construction at the same time. First measuring was carried out on iron-concrete samples of the size of 10x10x40 cm with built-in corroded and not corroded steel reinforcement of 8 and 10 mm in diameter.



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Fig. 4 – Testing on bridges

The AE impulses have been induced by hits with special hammer onto the surface of the concrete samples, later induced with dynamic loading in a loading presser, which complies better with the real conditions. From the analysis of signals gained when using the Fourier transformation we can see the difference of frequency characteristics between samples with the corroded reinforcement and samples with non-corroded reinforcement, see for example fig. 3.

The laboratory tests were followed by tests on real bridge constructions. The tests have so far been carried out on 5 bridges at different places of the Czech Republic. The AE signals have been induced by driving a dumping car Tatra over a wooden 15 cm high sill. The indicators have been placed on the bridge ceiling, see fig. 4. The results of the research are being continuously published, e.g. [12, 13].

4. CONCLUSION

The activity description of CDV in the field of the transport infrastructure technology mentioned in this article is obviously not complete, due to the limited extent of this article. So let me allow to give at least a simple list of other CDV activities. CDV currently or recently is or was working on other research projects: together with companies PONTEX, Motorway structures Prague (Dálniční stavby Praha) and SMP Construction, on a project of the Ministry of Transport (MD) “Cement concrete pavements on bridges”, see for example [14], and also on various projects of COST 343 – Reduction in Road Closures by Improved Pavement Maintenance Procedures, COST 344 – Improvement to Snow and Ice Control on European Roads and Bridges, COST 347 – Improvement in Pavement Research with Accelerated Load Testing, COST 351 Water Movement in Road Pavements and Embankments, COST 353 – Winter Service Strategies for European Road Safety, COST 354 – Performance Indicators for Road Pavements, TREE – Transport Research Equipment in Europe, etc.



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Determination of the carbon / hydrogen ratio in bitumen using prompt neutron gamma activation analysis

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Abstract

The paper presents a potential application of PGNAA method that allows the fast determination of colloidal index of bitumen compounds by a very fast analysis of hydrogen and carbon content. The H/C ratio thus determined is then correlated with colloidal index I_C . The regression line is given by the empirical relation $C/H = 5.9 + 34.1 \cdot I_C$ with a correlation factor $R=0.99$ and a standard deviation $SD = 0.71$. The perspectives of on-line applications are discussed.

1. INTRODUCTION

Bitumen is very important industrial material whose quality is connected with its chemical composition, which is controlled mainly by the crude oil processing technology. Though it comprises a great number of chemical compounds the following model appear to be in general accepted: The high molecular weight asphaltenes which tend to form sterical colloids dispersed in a lower molecular weight oily medium (maltenes). This "see" of maltenes in its turn is constituted from saturates, aromatics, and resins. The proportions of these molecular groups give the physical properties of various bitumen samples [1,2]. The colloidal index of bitumen is defined as a ratio of the total amount of asphaltenes and saturates to the amount of resins and aromatics. It describes the stability of colloidal structure.

Using a Prompt Gamma Neutron Activation Analysis (PGNAA) Set Up developed and installed at IFIN-HH; Bucharest we present an industrial application of this nuclear method devoted to a fast estimation of colloidal index of bitumen.

2. THE EXPERIMENTAL SET-UP

The experimental set-up consists of an Am-Be neutron source (10^7 n/s) placed in a cylindrical vessel and a semiconductor Ge-Li detector outside the vessel. The experimental arrangement is presented in fig. 1. The prompt gamma spectrum is recorded and analysed using an integrated computerised system. The energy



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calibration was carried out using the known prominent gamma lines in the different parts of the spectrum. The MCA soft provides the digital spectrum stabilization (DSS) by choosing a few known references peaks.

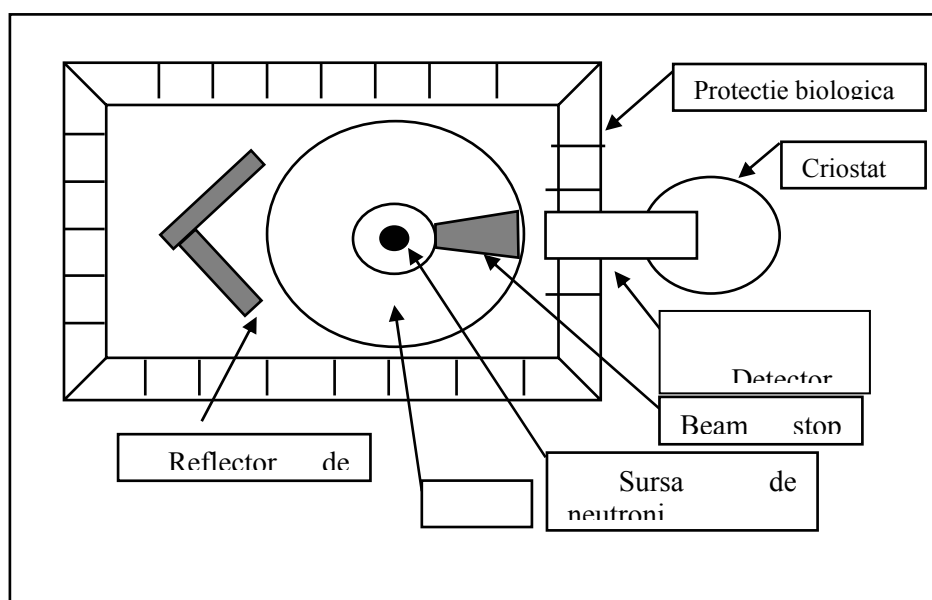


Fig. 1. PGNAA Schematic and view for experimental set up

3. PGNAA SPECTRA

The comments of the gamma lines obtained in such a geometry can be found in [3]. The PGNAA spectra were determined for three types of bitumen compounds. For exemplification in fig.2 the gamma spectrum for an ESSO sample is shown.

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The measuring time was one hour and the dead time was about 5 %. The inelastic scattering carbon lines are Doppler broadened.

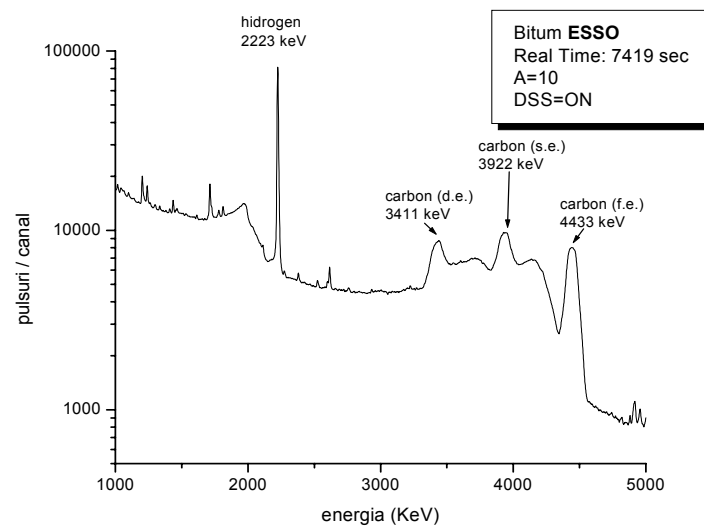


Fig.2. The PGNAA spectrum for ESSO bitumen sample

4. C/H RATIO

In order to determine the C/H ratio for bitumen by PGNAA method we used the thermal capture line of hydrogen at 2.22 Mev and the inelastic scattering (n, n', γ) of carbon at 4.43 Mev. The concentration of hydrogen will be given by:

$$\nu_H = \frac{A_H \cdot R_H}{\varepsilon(E_{H,\gamma}) \cdot I_{H,\gamma} \cdot \sigma_{\gamma,H}} \quad (1)$$

where A_H stands for atomic mass, R_H -the peak area of hydrogen capture line, $\varepsilon(E)$ is the detector efficiency at energy E of the line, I -the photon emission probability per captured neutron, while σ stands for thermal neutron capture cross section of hydrogen. In the case of carbon we deal with an averaged cross section on the fast neutron flux that is present in the sample:

$$\nu_C = \frac{A_C \cdot R_C}{I_C \cdot \varepsilon(E_{C,\gamma})} \quad (2)$$



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where A_C is the mass of the carbon nucleus, R_C is the carbon line area, $\varepsilon(E)$ is the detector efficiency at 4.43 Mev while I_C , the sensitivity factor is given by the following integral

$$I_C = \int_0^{E_{\max}} S'(E) \cdot \sigma(E) \cdot dE \quad (3)$$

It represents the averaged cross section on effective fast neutron flux $S'(E)$ normalised to unity. The value of this integral for an Am-Be neutron source placed in moderator medium, composed especially from carbon and hydrogen (like hydrocarbons, coal, or polymers) was calculated by Wormald.

$$I_C = 0,11029$$

The aromatic factor C/H will be given by the ν_C/ν_H ratio:

$$\frac{C}{H} = \frac{A_C \cdot R_C}{A_H \cdot R_H} \frac{\varepsilon(E_H)}{\varepsilon(E_C)} \frac{I_C}{\sigma_{\gamma,H}} \quad (4)$$

Here the value of σ_H is 0,332 barn, $A_C = 12$, $A_H = 1$, while the efficiencies ratio $\varepsilon(E_H) / \varepsilon(E_C)$ was obtained from the efficiency function of Ge-Li detector calculated by us by Monte Carlo simulations:

$$\frac{\varepsilon(E_H)}{\varepsilon(E_C)} = 1,23$$

The calibration of the experimental system was realized by using an graphite-alum mixture:



This compound contains:

H	6.2%
O	70.6%
N	3%
S	14.0%
Al	6.2%

The measurements were carried out on two such mixtures:

50% graphite	50% alum	C/H ratio = 16,13
70% graphite	30% alum	C/H ratio = 24.19



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In order to have a good homogeneity the two materials were very well chewed and the geometry of the system was kept identical. On the other hand the bitumen has a composition dominated by carbon (81÷86%), hydrogen (9.5÷10.8%), and sulfur (1.3÷6.9%). The comparison of PGNAA data with real mixture composition gave the following results:

Table 1. The main data of the calibration mixtures for check

Sample Number	Graphite / Alum ratio	C/H ratio mixture	C/H ratio PGNAA	Deviation (%)
1	50(%) / 50(%)	16,13	15,54	3,6
2	60(%) / 40(%)	24,19	25,48	5,06

The aromatic factor C/H will be given by the v_C/v_H ratio:

$$\frac{C}{H} = \frac{A_C \cdot R_C}{A_H \cdot R_H} \frac{\varepsilon(E_H)}{\varepsilon(E_C)} \frac{I_C}{\sigma_{\gamma,H}} \quad (5)$$

In the last relation σ_H is 0.332 barn, $A_C = 12$, $A_H = 1$, while the ratio $\varepsilon(E_H) / \varepsilon(E_C)$ was evaluated from Monte Carlo simulations

$$\frac{\varepsilon(E_H)}{\varepsilon(E_C)} = 1,119 \text{ (for second escape line of carbon)}$$

Replacing these values in (5) we obtain a very simple empirical formula for the evaluation of the aromatic factor C/H.

$$\frac{C}{H} = 40.5 \times \frac{R_C}{R_H} \quad (6)$$

For a given experimental arrangement the relation (6) allows the fast determination of this parameter that characterises the bitumen sample. This can be correlated with other technical parameters like viscosity, thermal susceptibility, and hardness if the correlation functions are apriori known. In the present work we correlated this ratio with colloidal index I_C , a technical parameter that is connected with bitumen composition that in its turn gives the microscopic structure. /1,2/. It is defined as a ratio of the total amount of asphaltenes and saturates to the amount of resins and aromatics. It describes the stability of colloidal structure.



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5. COLLOIDAL INDEX

Bitumen is composed generally by carbon (81÷86%), hydrogen (9.5÷10.8%), sulphur. (1.3÷6.9%). Small amounts of other elements are also present: oxygen, (1÷2 %), nitrogen (1÷2 %). Though the hydrogen content of bitumen is greater than in the case of our calibration mixture we used the same value of integral I_C . We can not appreciate the errors of this effect. The results are presented in the table 2.

Sample	Hydrogen peak area (counts/sec)	Carbon peak area (counts/sec)-double escape	Aromatic factor	Colloidal index
ARPECHIM	46,9	24,0	21,17	0.45
ESSO	93,33	30,94	13,4	0.23
EKO	96,07	13.45	3,31	0.29

Table 2. The results of PGNA analysis correlated with colloidal index.

In the first column are given the type of the sample. The final results were presented in fig. 3. The regression line can be described by an empirical relation.

$$C/H = 5.9 + 34.5 \cdot I_C$$

with a correlation factor $R = 0.99$ and a standard deviation $SD = 0.71$

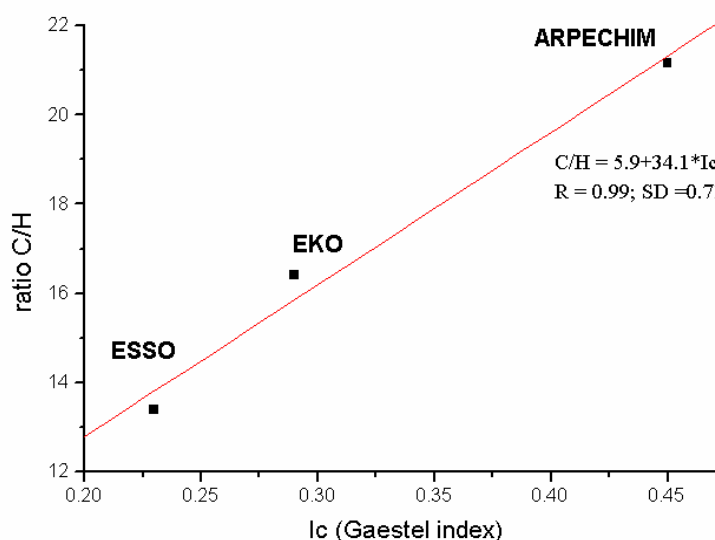


Fig.3. The aromatic factor C/H as a function of colloidal index.



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