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MODERN EUROPEAN METHODS OF NON-DESTRUCTIVE DIAGNOSTICS OF BRIDGE STRUCTURES

Abstract

Introduction. Various existing methods of non-destructive diagnostics, in particular for diagnostics of bridge structures are analyzed. However, nowadays in different countries of the world the researches are under way on the search for the most informative methods of non-destructive diagnostics of building structures, facilities, in particular bridge structures, which would enable to receive reliable data on the processes occurring in the structures under the influence of various factors.

Problem Statement. Existing methods of non-destructive diagnostics which are used for the diagnostics of bridge structures basically consist in periodic placement of sensors on structures. Having gathered information, the sensors are dismantled. Such actions are repeated as the time of the next inspection comes. In addition, measurements are fulfilled only at the discrete points, as the most devices and equipment have a limited operating range of measurements. The small amount of data received and the long interval between their acquisitions cannot provide signaling about the inevitable disaster that may be caused by various impact factors.

Purpose. The ultimate goal of the international scientific organization FEHRL, within the framework of which the SENSKIN Consortium works, is to develop a system for monitoring bridge structures in the framework of the international research project «SENSKIN» – «Sensing Skin for monitoring-based maintenance on the transport infrastructure».

Conclusions. Participants of the project «SENSKIN», including «DerzhorNDI» SE as a Consortium member, developed the sensors that will collect information on bridges, power supplies, data transmission and processing modules, software and other components of the bridge structure monitoring system. At this stage, the prototype of the monitoring system has been tested on the full-scale objects. Current information on the monitoring system can be found on the website of the SENSKIN Consortium http://www.senskin.eu.

For more reliable operation of non-standard bridges (the bridges which parameters exceed the limit values according to the adopted classification of bridges) in Ukraine, it is necessary to plan the transition to monitoring of bridge structures using the systems that would enable the acquisition of the necessary information about the state of structures in the event of catastrophic situations that will allow avoiding, in particular, the death of people.

Key words**:** automatic monitoring and management systems, sensor, methods of non-destructive diagnostics, non-standard bridges, monitoring system of bridge structures «SENSKIN».

Introduction

At present there are various methods of non-destructive diagnostics, in particular for the diagnostics of bridge structures [1]. However, the studies of the most informative methods of non-destructive diagnostics of building structures, facilities, in particular of bridge structures [2-6] are currently being conducted in different countries of the world. Non-destructive diagnostic methods should provide reliable data on the processes occurring in structures under the influence of various impact factors. These data should be sufficiently precise, and the expected errors should not exceed the permissible values. The received data during the diagnostics of bridge structures should be of sufficient volume for making correct decisions regarding the technical condition of bridge structures. The equipment and devices used to diagnose bridge structures should work reliably in different climatic conditions in which the bridge structures are found throughout their life cycle.

Monitoring of the structural state of bridges

Monitoring of the structural state of civil engineering infrastructure of Ukraine

Monitoring of the structural state of civil engineering infrastructure of Ukraine, in particular of bridges is carried out in accordance with state building regulations (DBN). The main document in Ukraine on this issue is DBN B.1.2-14-2009 [7]. It establishes general principles of ensuring the reliability and structural safety of buildings, facilities, building structures and foundations on the basis of the regulation of the reliability of their constituent parts during all stages of the life cycle of a construction object.

In order to achieve and maintain the necessary level of reliability and safety, in accordance with the DBN, it is necessary to effectively monitor and control the structural state of civil infrastructure objects at all stages of the life cycle of structures, buildings and facilities.

The purpose of the monitoring is to verify the compliance of the actual characteristics of the object with the requirements established for it.

The process of creation and use of the object and the results of the implementation of these processes are subject to monitoring, namely:

- execution of surveying works;
- project development;
- manufacture of materials and products;
- construction of a building object;
- technical operation, repairs, reconstruction.

The results of the control are used to make decisions about the possibility of completing the process or using its results or eliminating the detected non-conformity.

In the period of the construction and operation of the facility for the prevention of accidents, timely detection of damage and other defects, as well as for improvement of operating conditions, it is necessary to provide continuous inspection (monitoring) of the state of the object and adjacent territory.

The objects which destruction can lead to catastrophic consequences are equipped with automatic monitoring and control systems (ASMU). The ASMU must include a system of technical diagnostics of building structures which includes the following devices protected from damage:

- primary devices for obtaining information regarding the change of position (displacement) and state (deformation, temperature, etc.) of the inspected object;
- secondary devices for the processing of the received information (for example, computer system of the analysis of the state of the object, containing control standards and rules of decision-making);
- signaling devices;
- lines of communication between equipment and devices.

The necessity of applying such systems and requirements to them should be established by the design norms or rules of operation of the relevant objects.

Currently, such monitoring systems have not been used for bridges.

Analysis of the need for monitoring of bridge structures using non-destructive diagnostics on an example of real objects

In Ukraine, in accordance with current norms, the technical status of bridges is monitored during their life cycle [7, 8, 9].

Monitoring of the technical condition of bridges is carried out by the survey experts.

The survey expert, at the initial monitoring stage, periodically examines the bridge structures. The nature of the damage to the bridge structures is determined. In the case of detecting defects, the expert may decide on the need for a survey or test of the bridge using the devices and equipment.

The objects which failure (deterioration can lead to catastrophic consequences include, in particular, bridges, tunnels located on the main streets in the cities, since the failure of such an object can lead, for example, to the transport collapse of the entire neighborhood unit of the city. Below are the examples of such monitored objects.

For example, Figure 1 shows photos of bridge structures after a fire, as in the case of an overpass near the Shuliavska metro station in Kyiv. Here, in the course of the initial inspection, the defects of the concrete of the protective layer, of the fittings of the girders and the beams of the spans were detected [10].

a) b)

Figure 1 – Overpass structures near the Shulyavskaya metro station in Kyiv after a fire

The overpass consists of 17 spans of the split system.

Subsequently, the employees of the «DerzhdorNDI» State Enterprise carried out a special inspection of the overpass which was exposed to the fire. A special survey was carried out due to the deterioration of the technical condition of the three supports and three spans.

According to the results of research carried out on the construction of an overpass I was found out that in the spans 8 – 9, 9 – 10, 10 – 11 the greatest damage from the fire impact structures in the 8 – 9, 9 – 10 spans had undergone, and less damage was caused by the spans 10 – 11.

The duration of the fire, in accordance with the technical concclusion on the study of the causes of the fire, was of 78 – 85 minutes. At the same time, the data when the traffic on the overpass was blocked is not given in the report.

Specimens of concrete (corse) were taken to assess the impact of the fire on the strength of the structures of the overpass. The samples were taken from the body of the supports that were damaged and not damaged by the fire, in order to compare the characteristics of the concrete. Also, the samples were taken from the transverse beams' diaphragms.

Measurements of the deflections (vertical displacements) of the lower beams' booms in the 8 – 9 – 10 – 11 spans and the measurements in the spans that were not damaged by the fire were made to determine their possible increase and compliance with the admissible values.

In order to evaluate the influence of defects on the bearing capacity of the overpass structures, the static and dynamic tests were conducted.

During static tests the following was measured:

– deflections (vertical displacements) by mechanical devices (scale spacing was 0,01 mm) and an optical-digital leveler (scale spacing of the leveling rod was 1,0 mm);

– deformations (mechanical strain gauges) (price of the leveling rod was 0.004 mm);

– acoustic emission signals (software-technical complex «AKEM» on the basis of a personal computer).

Acoustic emission converters were installed on the concrete surfaces of beams of the spans structures that were damaged and, for comparison, not damaged by the fire in the middle of the span and on the console of the 9 th girder of the support.

During the dynamic tests the following was measured:

– mechanical vibrations on the surface of the bridge decking in the middle of the span over one of the beams using (software and hardware complex «FREQS»).

As a result of the fulfilled work, the conclusions were obtained, some of which are presented below:

– as a result of the visual inspection and the results of dynamic tests, it was found out that 8 – 9, 9 – 10 spans were the most damaged by the fire, the spans 10 – 11 were less damaged;

– the limiting load on the damaged spans of the overpass is as follows: for a motor vehicle load in a column is 10 ton-force, the permissible load on the axle of the car is 7 ton-force;

– the results of the survey of the overpass indicate that at the stated load levels due to changes in the characteristics of materials under the influence of high temperatures the initiation and development of the chanses on the macro level will occur;

– the overpass needs reconstruction including replacing and strengthening the supports of the spans 8, 9, 10 and the beams of the spans 8 – 9, 9 – 10, 10 – 11, according to a specially designed project.

For further temporary operation of the facility, the following preventive measures were taken to strengthen the structures damaged by the fire in order to avoid an emergency:

– urgent measures to be taken for traffic management in order to comply with the operating conditions of the structure in accordance with the established restrictions on the load for trafffic;

– after that, the structures for the reinforcement of the supports 8, 9, 10 and the beams of the spans 8 – 9, 9 – 10, 10 – 11 were installed according to a specially designed project;

– to strengthen the supports and the beams, at least once a week, the check tests of the state of damaged bearing structures should be carried out;

– after the construction of the reinforcement structures in 2007, the restrictions on the dimensions of the bridge decking and load capacity were removed;

– during the operation of the overpass with a temporary reinforcement in order to ensure its trouble-free operation, once a month, the check tests are carried out.

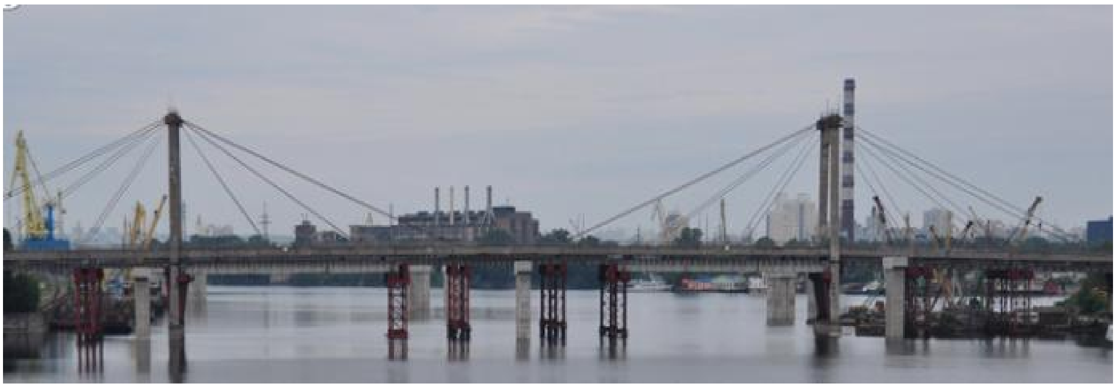
As noted above, in the presence of equipment and highly qualified specialists, «DerzhdorNDI» State Enterprise managed to carry out a special inspection of the fire superstructure and to develop preventive measures to strengthen the structures damaged by the fire in order to avoid an emergency. In this case, in particular, the deflections of bearing structures were determined; it was found out which of the structures of the spans were the most damaged; in what structures and how much the carrying capacity and stiffness decreased. To do this, instrumental measurements were carried out on both, damaged and non-damaged structures. It should be noted that the survey work was carried out extremely quickly (immediately after the fire), since the closed bridge virtually paralyzed the traffic in the whole microdistrict of the city. At the same time, although the works were carried out with the observance occupational safety, it was necessary to work on the remnants of fire, where there was still fumigation, including at night.

Another example of the collapse of the bridge which considerably complicated the pedestrian connection of the neighborhoods of the city's districts is the collapse of the bridge across the Dnipro Harbor in Kyiv (Figure 2).

Here, the damage to the bridge structures arose as a result of prolonged operation. For example, after prolonged operation, the defects in the structures, in particular, the cable stays of the bridge over the Harbor of the Dnipro River in Kyiv (Figure 2), were found.

Unfortunately, due to various reasons, the survey of the bridge structures was not carried out timely. Accordingly, the repair works were not performed in time. As a result, the propagation of defects occurred which led to the gradual weakening of the bridge and its failure.

In the case of a monitoring system availability (monitoring system which would provide the data on, for example, cable stays deformation) of the structures of this object prior to the occurrence of irreversible deformation of the cable stays, it would be possible to receive timely information on the damaged cable stays. Subsequently, if required, to perform a special survey, repair (or replacement) of the cable stays, thereby extending the bridge operation term.



a)

b)

Figure 2 – Damage of the bridge structures over the harbor of the Dnipro River in Kyiv due to prolonged operation

Taking into account the above, one can note the advantages of having a monitoring system on the objects of transport facilities:

– in case of a fire, it is possible to react quickly to the situation, in particular, with regard to limiting or closing the traffic on the bridge, which will protect people's life and health. In addition, often an expert can not access all necessary parts of the facility to obtain the necessary information;

– in the event of failure of defining (bearing) structures, it is possible to quickly obtain information on which structures have been out of order;

– during monitoring it is possible to receive notification about the critical values of deformations caused by damage or deterioration of structures. In this case, the monitoring experts are at a safe distance from the monitoredg facility;

– it is possible to obtain data on the deformations of the defining elements during operation and to establish their conformity with the admissible values without closing the traffic for the time of inspection or testing;

– the possibility of prolonged operation of the monitoring system's sensors and their stable operation, including under the influence of repeatedly deformations, allows receiving a considerable amount of information about the state of the structure with relatively low costs on the sensor.

Methods of diagnosing the technical state of the bridges

It is possible to use equipment that measures deformations in structures. These are various strain gauge complexes and mechanical devices.

Other type of equipment is the equipment, the work principle of which is based on the measurement of acoustic emission signals (AE). Acoustic emission (AE) is a phenomenon which is based on the emission of elastic waves in solids due to the local and dynamic rearrangement of the internal structure of the material. Block scheme of registration of AE signals is shown in Figure 3.

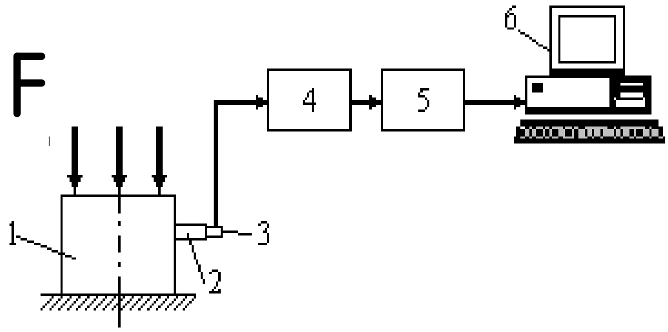


Figure 3 – Block scheme of registration of AE signals: 1 – the studied element (structure) which is under the influence of F; 2 – wave conductor; 3 – AE sensor; 4 – amplifier; 5 – computer connection port; 6 – PC

Such equipment records the formation and development of defects, in particular, the occurrence and propagation of cracks.

The employees of the State Enterprise «DerzhdorNDI» developed methods for determining the characteristics of building products and structures using the AKEM equipment which allow the determining of micro- and macro cracks formation in metal material or in the reinforced concrete structures.

Figure 4 shows the general view of the software and hardware complex «AKEM».

Figure 4 – General view of the software and technical complex «AKEM»

Tests within the monitoring can be performed both during the day and at night depending on the object of the monitoring.

Several parameters are used to analyze the signals. One of these parameters is the coefficient Kp of AE signals.

Figure 5 shows a graph of changes in the coefficient Kp of AE signals that were recorded during testing the bridge span. The temporary load on the bridge span according to the loading scheme is one car.

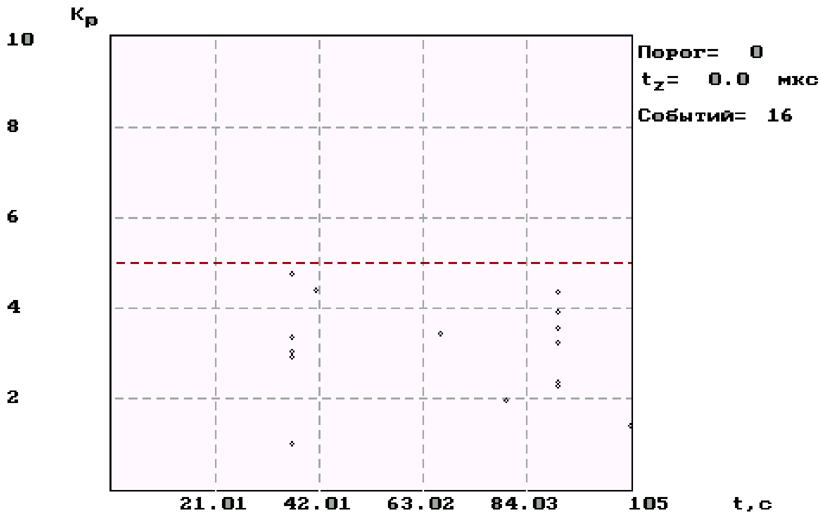


Figure 5 – Graph of changes in the coefficient Kp of AE signals that were recorded during testing the bridge span

In this case, according to the results of the conducted researches using the AE method, it is established that the temporary load on the bridge span created during static tests causes the formation of micro and macro cracks in the metal structure. A limit for structure loading was determined, the excess of which can create dangerous propagation of defects which were available in structures that could lead to an emergency situation.

Also, other parameter that can signal on the presence and propagation of defects can be the parameter «accumulation of energy of signals of acoustic emission» (Figure 6).

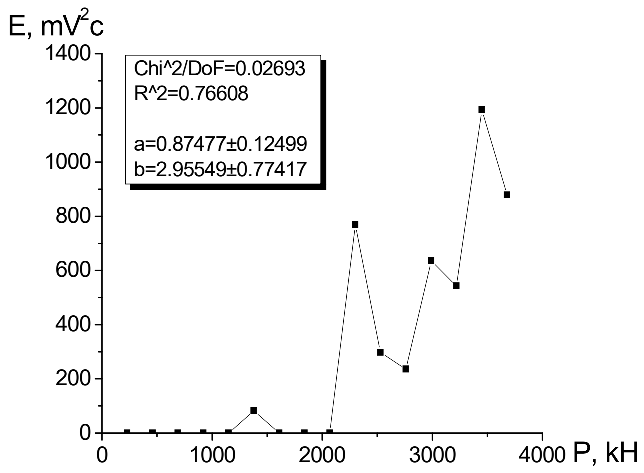


Figure 6 – Graph of changes in the parameter «accumulation of energy of signals of acoustic emission» depending on the values of the applied load which were recorded during the test of the bridge span

Changing the value of this parameter reflects the technical state of the structure. For example, during the analysis of this parameter it was established that the values of the energy of the acoustic emission signals recorded in the material of the structures of the bridge span before the reinforcement of structures significantly exceeds the energy of the acoustic emission signals after reinforcement.

The AE method is one of the methods for diagnosing the bridges state. Diagnostic methods developed based on it can be effectively used for monitoring the technical state of the bridges.

Modern European methods of non-destructive diagnostic of bridge structures

Project «SENSKIN»

The international scientific organization FEHRL have been developing a system for monitoring the bridge structures in the framework of the international research project «SENSKIN» – «Sensing Skin for monitoring-based maintenance on the transport infrastructure» within the European Commission Program HORIZON 2020.

SENSKIN is an EC co-funded project that operates in the framework of EC-FP7-Transport (MG-8.1a-2014 - Smarter design, construction and maintenance). SENSKIN includes a consortium with all the expertise needed in the lifecycle from research to innovation, as well as real-life end-users that can provide solid feedback on the project results. The list of partners of the consortium has been presented below:

Partner Name	Short Name	Country
Institute of Communication and Computer Systems	ICCS	Greece
University of Potsdam, Applied Condensed-Matter Physics Group	UP	Germany
Egnatia Odos A.E.	EOAE	Greece
RISA Sicherheitsanalysen GmbH	RISA	Germany
TECNIC S.p.A.	TECNIC	Italy
Democritus University of Thrace	DUTH	Greece
Mistras Group Hellas A.B.E.E.	MGH	Greece
University of Stuttgart	USTUTT	Germany
TRL Limited, Transport Research Laboratory	TRL	UK
State Enterprise State Road Scientific Research Institute	DNDI	Uktraine
Forum Des Laboratoires Nationaux Europeens De Recherche Routiere	FEHRL	Belgium
Teletronic Rossendorf GmbH	TTRONIC	Germany
Turkish General Directorate of Highways	KGM	Turkey

The participants of the project, a member of which is also the DerzhdorNDI SE, at different stages of the project solve different tasks such as development of the requirements for the method of non-destructive diagnostics of bridge structures. It included collecting and analyzing the data on existing approaches for monitoring the bridge structures state in different countries by the project participants: which devices, equipment, monitoring methods are used in this case; who carries out monitoring of bridge structures in different countries and with what difficulties, in this case, performers of works face. The result of this data collection and analysis was the work tasks for further development of the monitoring system for bridge structures approved by the project participants.

At the next stages, the project participants developed a sensor that will collect information on bridge structures, power supplies, data modules, software and other components. Particular attention was paid to the development of sensors because the task was to develop quite universal sensors which can be used for monitoring the concrete, reinforced concrete and metal structures of bridges. For this purpose, a multilevel method of checking the characteristics of the sensors was used: the mechanical properties of the sensors were determined in the laboratory. The further studies were carried out on the location of the sensors on the samples that simulated the bridge structures. At the final stage, the study of the sensors on the full scale structures was carried out.

At the current stage, a prototype of the monitoring system which was approbated on full scale objects was manufactured. Relative information on the monitoring system can be found on the website of the SENSKIN Consortium http://www.senskin.eu.

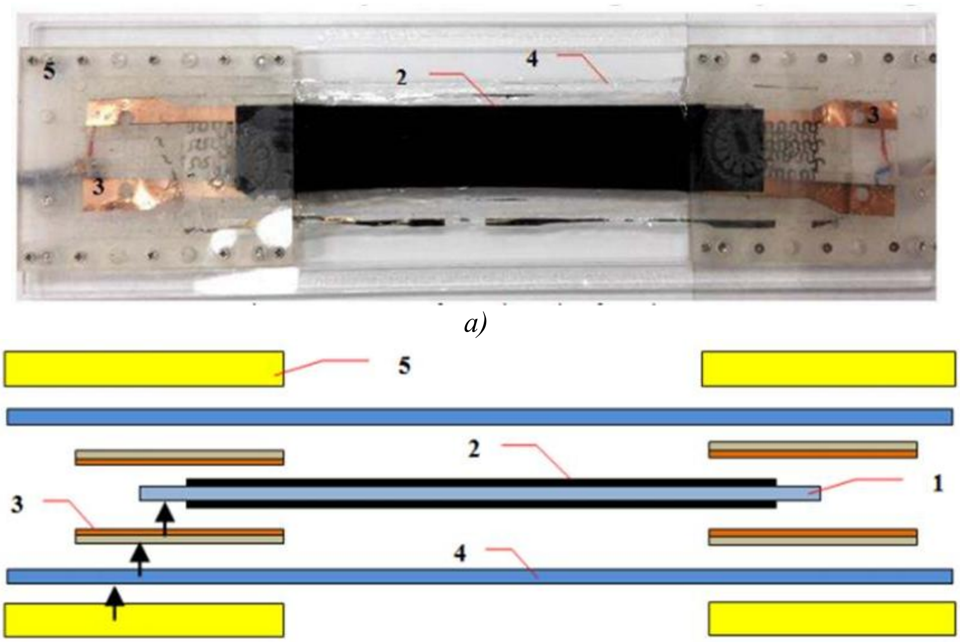
«SENSKIN» sensor

The SENSKIN system consists of a sensor similar to dielectric elastomers and microelectronics based on the use of a large expandable membrane with a sensitive capacity. The sensor ensures spatial measurement of the strains exceeding the values of 10%, it has several advantages in comparison with the similar sensors such as: needs low power for operation, easy to install, has a comparable or less cost than conventional strain sensors, allows simple signal processing, has the opportunity of independent monitoring and reporting. The system supports the network technology which ensures that received stresses measurements reach the base station even under extreme conditions where communication can fail. The SENSKIN project also develops a decision support system (DSS) for proactive structural interventions based on conventional operational conditions and response emergency measures in case of accident. Assessing the potential rehabilitation options, DSS will use the data provided by SENSKIN sensors along with extended models of structural analysis taking into account the economic, social and environmental impacts of the lifecycle.

The principle of work of a skin-like sensor is based on the periodic measurement (monitoring) of changes in capacity caused by the strain of the sensor. It is well known that capacity C of a parallel plate capacitor can be presented as follows:

$$C = \varepsilon\varepsilon_0 A / d \qquad (1)$$

where A is the area of the capacitor, d is its thickness, and ε and ε_0 are the relative dielectric penetration of the material of the sensor (i.e., the capacitor dielectric) and the vacuum dielectric penetration in the SI system, respectively. If any of the above parameters changes, the capacity will also change. Thus, if the capacitor is attached to any substrate, the strain of the substrate leads to a change in the capacity of the sensor. For recording the large strains of the substrate, the capacitor must be fairly soft, that is, it should be able to change its linear dimensions within the elastic strain, and the electrodes must also remain conductive throughout the designed or expected range of movement. In order to meet these requirements, a soft capacitive sensor which is manufactured from silicone rubber films with corresponding electrodes was developed. Since the elastomeric material is essentially incompressible, an increase in the area A in equation (1) will necessarily be associated with a decrease in thickness d. Both combined processes lead to a linear increase in capacity when the sensor is stretched, for example, in length or width. The view of the capacitive sensor and its design can be seen in Figure 7.



b)

***Figure** 7 – a)*: SENSKIN sensor (top view); *b)*: SENSKIN sensor (design scheme): 1 – silicone film; 2 – conductive layer (with a type electrical resistance of 0.1 – 10 kOm per 15 cm in length); 3 – electrical contacts connected to the conductive layer; 4 – silicone protective layer which seals the sensor; 5 – external frames used for mounting the sensor in the test device

Sensor parameters: Active electrode area is 15x3 cm^2. The capacity without pretension is from 2.3 to 2.5 nF. Typically, the sensitivity is from 2 to 2.5 fF / micro strain. The resistance of the electrodes varies within 0,02 – 0,07 Om / micro strain. Being made from soft elastomeric materials, sensitive capacitors can withstand mechanical stresses that exceed 300 % without losing their integrity. It is proved that the electric characteristics of the sensor perform well within 100 % of its strain.

Data collection system

The challenge for data collection is the measurement of relatively small changes in capacities caused by stretching compared to the large basic capacity of the sensitive element of the SENSKIN sensor. The limitation for the data collection system is the relatively high contact resistance of the sensor which varies from 100 Om to 10 kOm. Thus, for data collection there is a need in capacity for digital convector (CDC) with a high resolution and a huge dynamic range. The data collection system module consists of an analog part and the next digital signal processor (DSP). The DSP module provides processing of the low-level signals as average value and supports the adaptation of sensor parameters, as well as the requirements for measuring technology by programming at the assembler level. The time of discharge of the internal circuit resistor and the unknown capacity of the sensor, on the one hand, and the control capacitor, on the other hand are measured from the analog part. The sensor capacity is determined by comparing the discharge cycles. The disadvantage of this measurement principle is the resistances of the tensile electrode of a sensitive capacitor which significantly impacts on the measurement result. Therefore, the system that includes the sensor must be calibrated and the calibration results must be recorded in the DSP. The data collection system is located on the investigated structure, at a certain distance from the sensor.

Communication system of SENSKIN

SENSKIN communication system is based exclusively on wireless telecommunication technologies.

SENSKIN communication system consists of three different elements:

1. SENSKIN nodes. These are SENSKIN devices located at different places of the bridge (bridge parts). Each SENSKIN device is equipped with a communication module.
2. SENSKIN gateways. They are a platform for intermediate software for the interconnection of the deployed SENSKIN network with a remote administration tool.
3. SENSKIN security nodes. Their main difference is that they are mobile.

Control system in SENSKIN

At this stage, the work is underway to improve the control system in SENSKIN which includes the calculation modules, the formation of the SENSKIN database structure, the development of the end-user interface, the module of measurement data processing obtained from the sensors. All of these modules are initerlinked through a control module. The control module provides efficient and accurate data exchange between individual applications.

The SENSKIN database, as the central repository of information, provides relevant input data and obtains output from calculation or information modules (e.g., sensor data, environmental and economic profiles, status states for various bridge elements, etc.).

The user interface serves to graphically visualize the results.

Approbation of the measuring equipment for monitoring the technical state of the bridges «SENSKIN» (Sensing Skin) on the bridge over the Bosporus (Istanbul, Turkey)

In May 2018, approbation of the measuring equipment for monitoring the technical state of the bridges was carried out. Approbation was performed on the cable bridge over the Bosporus (Figure 8).

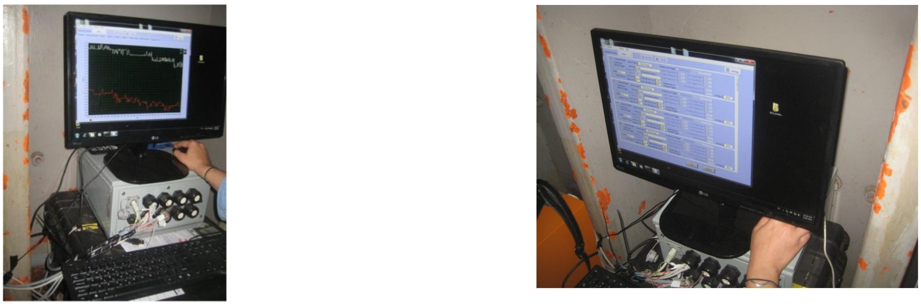
Figure 8 – General view of the bridge over Strait of the Bosporus

The sensors and other elements of measuring equipment were located on the bridge structures over the Bosporus (Figure 9).

Figure 9 – «SENSKIN» sensor, solar cell, data modules are placed on the surface of the bridge pylon

The «ENSKIN» sensors were placed both on the opposite sides of the bridge footing and on the lateral part of the bridge footing. The expert's workplace was equipped in the middle of the bridge pylon bearing.

The results of the measurements of the «SENSKIN» sensors were displayed on the monitor in the form of graphs (Figure 10, a) and data tables (Figure 10, b) by using specially designed software.



a) *b)*

Figure 10 − The results of the measurements of the «SENSKIN» sensors on the monitor: *a)* graphs; *b)* data tables

Conventional strain sensors were placed alongside the SENSKIN sensors to perform parallel measurements that were forwarded to the central SENSKIN database and were used to evaluate and compare the technical characteristics of the SENSKIN sensors. The sensor was evaluated in comparison with the conventional tensor strain gauges in terms of the quality of measurements: accuracy, sensitivity, noise threshold; useful measuring range; the sensor's response on the changes in temperature and humidity; strength, durability and lifecycle of the sensor during cyclic loading and weather conditions. The technical and operational performance of the whole SENSKIN system which consists of SENSKIN sensors, data acquisition system modules, communication elements and data transmission, was assessed. Ease of use of the entire system, interpretation of the source data of the system to support engineering assessment and the ability to self-control and self-assessment of hardware and software malfunctions was also assessed.

By the use of «SENSKIN» equipment, the data on the operation of the bridge structure elements were obtained. Further, the obtained data will be analyzed by the specialists involved in the SENSKIN project.

Conclusions

1. The international scientific organization FEHRL have been developing a system for monitoring the bridge structures in the framework of the international research project «SENSKIN» – «Sensing Skin for monitoring-based maintenance on the transport infrastructure» within the European Commission Program HORIZON 2020.
2. The participants of the project, a member of which is also the DerzhdorNDI SE, developed a sensor that will collect information on bridge structures, power supplies, data modules, software and other components of monitoring system of the bridge structures.
3. At the current stage, a prototype of the monitoring system which was approbated on full scale objects was manufactured. Relative information on the monitoring system can be found on the website of the SENSKIN Consortium http://www.senskin.eu
4. For more reliable operation of non-standard bridges (the bridges which parameters exceed the limit values according to the adopted classification of bridges) in Ukraine, it is necessary to plan the transition to monitoring of bridge structures using the systems that would enable the acquisition of the necessary information about the state of structures in the event of catastrophic situations that will allow avoiding, in particular, the death of people.

For carrying out the monitoring in addition to the necessary equipment the following issues need to be solved:

– providing the arrangement of stationary monitoring systems on the non-stzndard bridges that would inform on the emergency situations (eg critical deformation of structures, the rise of water level, etc.);

– improvement of regulations on the order of data provision according to the monitoring results (clarification of the passport of the bridge which contains information on existing defects and their volume). It is needed for further planning of bridges repairs.

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СУЧАСНИЙ ЄВРОПЕЙСЬКИЙ МЕТОД НЕРУЙНІВНОЇ ДІАГНОСТИКИ МОСТОВИХ КОНСТРУКЦІЙ

Анотація

Вступ. Проаналізовано різні існуючі методи неруйнівної діагностики, зокрема, і для діагностики мостових конструкцій. Проте, в даний час в різних країнах світу продовжують виконувати дослідження щодо пошуку найбільш інформативних методів неруйнівної діагностики будівельних конструкцій, споруд, зокрема, мостових конструкцій, які б давали можливість отримувати достовірні дані щодо процесів, які відбуваються в конструкціях під дією різних факторів пливу.

Проблематика. Існуючі методи неруйнівної діагностики, які використовуються для діагностики мостових конструкцій, полягають, в основному, у періодичному розміщенні давачів на конструкціях. Зібравши інформацію, давачі демонтуються. Такі дії повторюються, коли настає час наступного обстеження. Крім того, вимірювання виконують тільки в дискретних точках, більшість приладів та обладнання мають обмежений робочий діапазон вимірювань. Мала кількість отриманих даних та великий інтервал між їх отриманням не можуть забезпечити сигналізацію про неминучу катастрофу, яка може бути спричинена різними факторами впливу.

Мета. Кінцевою метою Міжнародної наукової організації FEHRL, в рамках якої працює Консорціум «SENSKIN» є розроблення системи моніторингу мостових конструкцій в рамках міжнародного науково-дослідного проекту «SENSKIN» (Чутлива шкіра) для технічного обслуговування на основі моніторингу транспортної інфраструктури.

Висновки. Учасниками проекту «SENSKIN», членом якого є ДП «ДерждорНДІ», розроблено давачі, які збиратимуть інформацію з конструкцій мостів, джерела живлення, модулі передачі та обробки даних, програмне забезпечення та інші компоненти системи моніторингу мостових конструкцій. На даному етапі апробовано прототип системи моніторингу на натурних об'єктах. Актуальну інформацію щодо системи моніторингу можна знайти на сайті Консорціуму «SENSKIN» http://www.senskin.eu .

Для більш надійної експлуатації позакласних мостів (мостів, параметри яких перевищують граничні значення згідно з прийнятою класифікацією мостів) в Україні необхідно планувати перехід на моніторинг мостових конструкцій із використанням систем, які б давали можливість отримувати необхідну інформацію про стан конструкцій у випадку виникнення катастрофічних ситуацій, що дасть можливість уникнути, зокрема, загибелі людей.

Ключові слова: автоматичні системи моніторингу і управління, давач, методи неруйнівної діагностики, позакласні мости, система моніторингу мостових конструкцій «SENSKIN».