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Integrated earthquarke alarm system for monitoring the bridge and road by sfg0 and rdm sensor

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Abstract

This research project aims to improve earthquake alarm systems which aim to monitor bridges and road systems. The system monitor in real-time the stability of the structures and to report the state of alarm in the national emergency. To bridges monitoring we determining the stresses at critical points also in the event of a catastrophe where the bridge loses its stability and consequently collapses, the SFG-0 sensor will send the data to the national emergency server. To monitor the road system will be used the RDM sensor, through which we identify the position and extent of road damage in case of landslides or other damage caused by the earthquake.

Key words: SFG-0 Sensor, RDM Sensor, earthquake alarm system, emergency server

1 Introduction

Through this system, we can monitor in real-time the bridges and the road system to determine the degree of their damage from a seismic shock. We are clear that with current technologies it is not possible to predict the exact place and time when and where an earthquake will occur, but we can monitor structures to ensure that they are still ready to continue service or should be considered as damaged or at risk of destruction. Bridge monitoring has a high advantage as often the structure can resist seismic shock but its stability will be weakened thus posing a risk of collapse. If the stability of the bridge is endangered then the network of sensors installed in its columns will signal the weakening of the structure. Through this study, the aim is to create a reliable and stable monitoring system over time. This system provides information if the bridge collapses and warns vehicles to avoid heading towards it.

Another advantage is the monitoring of the road system which has as a warning function for possible landslides or the identification of damaged segments. By monitoring the road system, traffic management conditions can be created to avoid damaged segments.

A similar monitoring system through the use of an RDM sensor can be applied to the rail network. In the event of any possible rail damage, the system will alert the train driver to avoid exited derailment.

2 Bridge monitoring system

Monitoring the seismic stability of bridges will create the conditions of an alarm system in case of risk of its collapse. After the shock force of the earthquake causes serious damage to its structure, the stability of the bridge will be questioned by requesting a verbal inspection or through measurements by the civil engineer or its constructor [1]. But this process takes a long time and delays would bring obstacles to the transportation of people and materials. It should be noted that vehicles may attempt to cross the bridge immediately after the end of the first seismic shock, wherein these conditions the bridge is still untested and presents a serious risk of collapse thus becoming a source of the accident. To avoid the above defects, it is necessary to implement an alarm system for bridge monitoring. This system will use several types of sensors to carry out the measurement process, the typology and characteristics of the sensors which will be used depend on the type of bridge and its construction.

2.1 Typology of applied sensors

In these constructions, the monitoring can be realized by means of a network of strain gauge sensors, which will be installed in the steel of the columns as shown in Figure 1 [2].

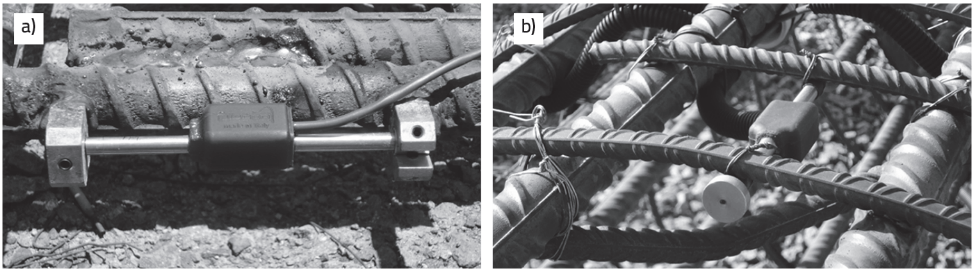

Figure 1. a) Strain gauge sensor configuration 1; b) Strain gauge sensor configuration 2

The typology of these bridges allows plastic displacements with small amplitudes and in these conditions, the use of strain gauge sensors would bring satisfactory results, but in case the columns are displaced with large amplitudes a part of the bridge section will try to be displaced from the sections other. In this case, the RDM sensors installed between the sections could perform the displacement measurement [3].
For bridges with steel structures can allow plastic oscillations with different amplitudes from those of reinforced concrete structures. Even in these constructions, the RDM sensor will be installed in the connecting parts of separate sections to measure and to determine the distances of their displacements, these displacements can be both in the longitudinal axis and in the transverse axis.
In the fatal case, when the bridge loses its viability and the structure collapses, the SFG-0 sensor shown in Figure 2 [4], will detect the collapse of the structure and alert the national emergency to the red alert status on the destruction of the bridge.

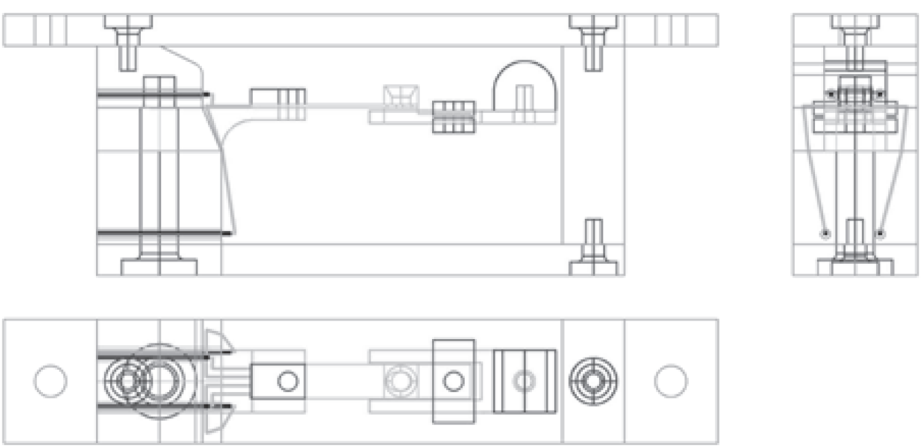

Figure 2. SFG-0 sensor design

This is a new sensor to detect when structure destroyed. The zero gravity sensor could enable the detection of free fall or induced acceleration of the structure. This sensor has a metal plate inside it with a mass at its edge while on the other side it is supported, as shown in Figure 3 . When the earthquake destroys the structure, the object will fall by inducing on the ceiling an acceleration which will reduce the weight of the object on the curved sensor plate by changing the bending position.

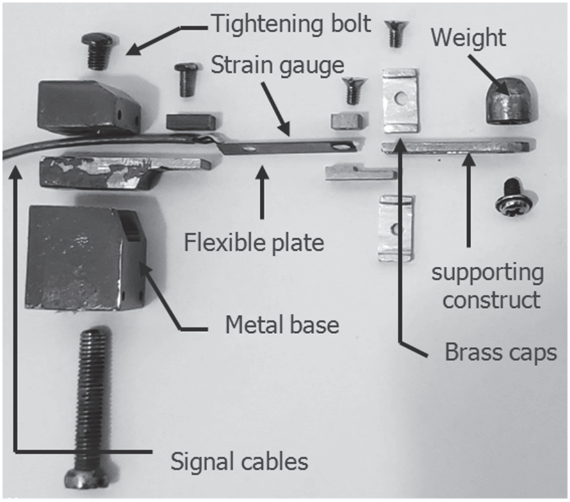

Figure 3. SFG-0 constructs

The change in curvature will be accompanied by the change in the strain at the support point which can be identified by the strain gauge sensor, located on the surface of the curved plate. Knowing the value of the strain gauge resistance when the ceiling was in the static position we can determine the state of exit from equilibrium if we determine from the measurements different value of the resistance.

2.2 RDM Sensor (Road Displacement Monitoring)

The RDM sensor is a new sensor designed in Albania in order to measure the displacements of structures, this sensor works based on the delay time that the ultrasonic sound needs to travel from the transmitter to the receiver. In its sensor design, as shown in Figure 4, the RDM sensor has an ultrasonic transmitting probe placed in the transmitting tube which has a smaller diameter than the receiving tube, manages to enter its interior. The ends of the sensor are tightened by means of tightening bolts to the structure to be monitored. When the structures are moved against each other as a result of the action of seismic force, the ends of the RDM sensor will be retracted, thus changing the penetration of the transmission tube to the receiver. In itself, this process finds in the reduction of the distance of two ultrasonic probes and consequently, the passage time of the sound wave will be variable depending on the distance.

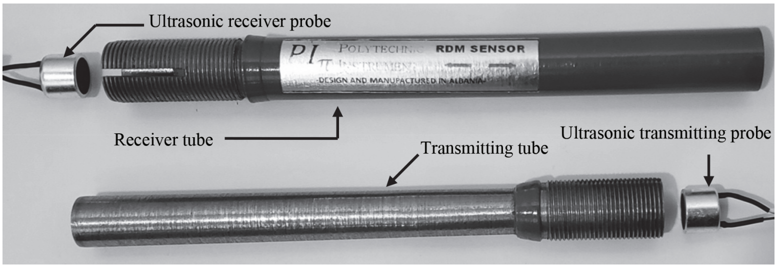

Figure 4. RDM Sensor constructs

By knowing the sounds speed propagation in a gaseous environment known as air, we can determine the time it takes for the signal to reach from the transmitter to the receiver. The distance between the two probes will be determined according to equation (1):

$$D = \nu \cdot \tau \quad (1)$$

Where:
d – distance; *v* – air sound speed; τ – time

The speed of propagation of sound in air is determined to be 343 m / s to 20°C temperature, but this speed depends on the elastic properties of the body (as a module of compression or Young's modulus) and properties inertial environment (the linear density or volumetric). Inside the transmission and receiver tube of the RDM sensor is a gaseous volume of air, where for the air we know that the compression modulus is in direct proportion to the pressure and that the pressure is in direct proportion to the volume density ρ and the absolute temperature *T* of gas. Under these conditions, it is concluded that the speed of sound propagation in the internal environment of the RDM sensor can be determined according to equation (2):

$$v = \sqrt[2]{\frac{\gamma \cdot R \cdot T}{M}} \quad (2)$$

Where:
v – air sound speed; *T* – absolute temperature; *R* = 8.3214 J/(molK) - general gas constant; *M* = 0.029 kg/mol - gas molar mass; γ = 1.4 gas constant

Understandably, changing the temperature of the gas would bring about a change in the speed of sound propagation in it. Under these conditions, even if the distance between the terminals of the RDM sensor remains the same (the structure is stable), changing the speed of sound propagation would cause the delay time of the sound signal from the transmitting probe to the receiver to change. This scenario would bring false alarms to the monitoring system and to prevent this phenomenon the necessity for temperature monitoring arises [5].

2.3 RDM sensor system experimentation

During the experimental tests, the RDM sensor was placed at low temperatures through a refrigeration machine to stimulate the low operating temperatures. Then we increase the temperature of the sensor to high levels by placing it in working conditions with high temperatures. The dynamic change in temperature is shown in Figure 5, and we notice a large change in the sounds speed propagation inside the RDM sensor wave transmission section.

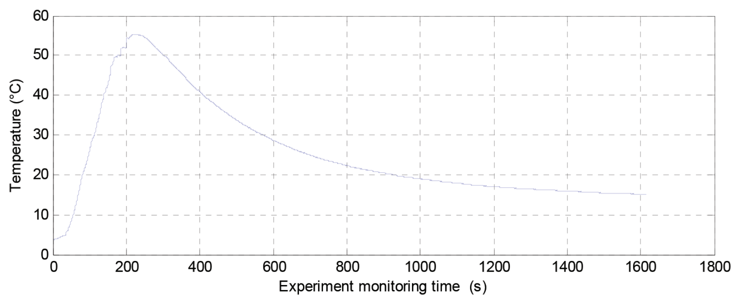

Figure 5. Dynamic change of temperature during the experimental phase

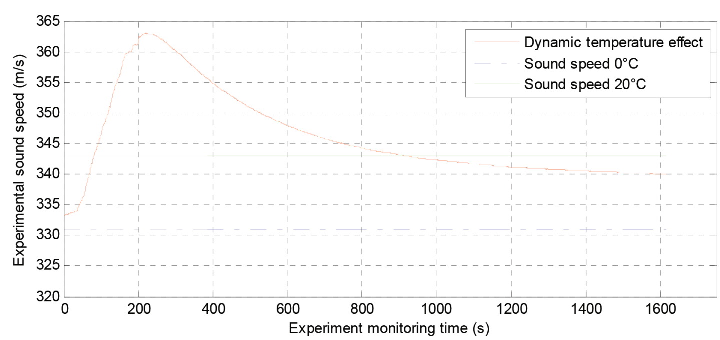

Figure 6. Dynamic change of sound speed during the experimental phase

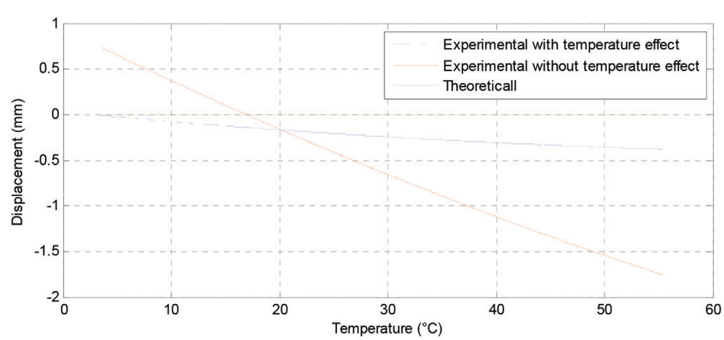

Figure 7. Dynamic change of displacement during the experimental phase

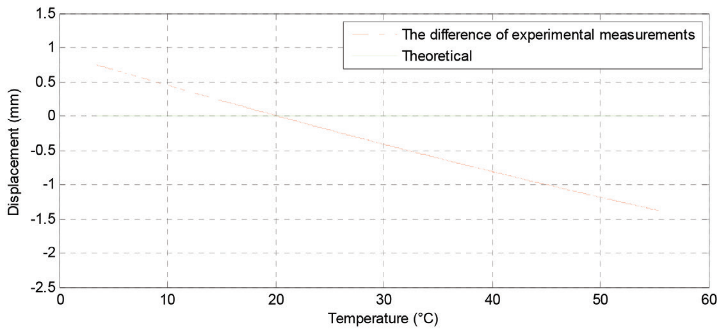

Figure 8. Dynamic change of displacement difference during the experimental phase

In the case where the temperature is taken into account, the displacement is close to the theoretical real value. Of course in the experimental measurements, we distinguish a slight displacement of 0.4mm, this displacement has come as a result of the material linear swelling on which the edges of the RDM sensor are supported. Whereas in case the effect of temperature is neglected, the displacement reaches large values and puts the system near the alarm state by increasing the premises for false alarms. In Figure 8, we distinguish the difference between the two displacement situations above where it is noticed that their difference is a considerable value and is proportional to the temperature. We conclude that a further temperature increase would cause an increase of error according to the method when temperature measurement is neglected.

The measurement signal output from the RDM sensor will be sent to a microcontroller which will send it through the COM Port to the software to process and analyze it. LabView software was used to perform the experiments, in which the interface shown in Figure 9 was built [6, 7].

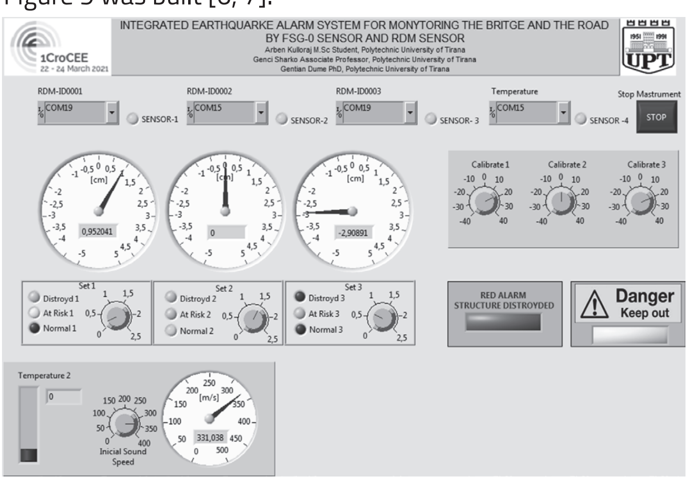

Figure 9. RDM Sensors interface to LabView

In this digital platform, many sensors can be connected at the same time, creating extensive real-time monitoring. The platform is programmed to enable the initial sensor's calibration, the manual setting of the sound speed in certain environmental conditions and can reflect the risk of a possible collapse of the structure when the distortions are bigger than the allowed values. The maximum structure displacements allowed values are given by the constructor and are loaded in the system manually in the process of installing the monitoring platform [8].

3 Road monitoring system

3.1 Road monitoring

The earthquake force can cause partial or complete damage to the road system, causing traffic problems or endangering the life of the road user by a sudden road slip. The earthquake effect monitoring system on the road system can be realized using the classic version of the RDM sensor presented in Figure.10. The sensor is constructed by several connectors placed one after the other which are connected to the ends of resistors with different ohmic values. As a result of the displacement of the removable connector different values of equivalent output resistance will be obtained [9].

The extreme edges are fixed to the road structure and when the earthquake causes its damage by causing displacement or cracking of the asphalt, the sensor terminals will be displaced towards each other as a deformation of the asphalt layers by the action of the force. The big road structure deformation will cause the pulling of the edges of the RDM sensor. In some cases, the force may be in the repressor direction, causing the asphalt layers to overlap, in which case the edges of the sensor approach each other.

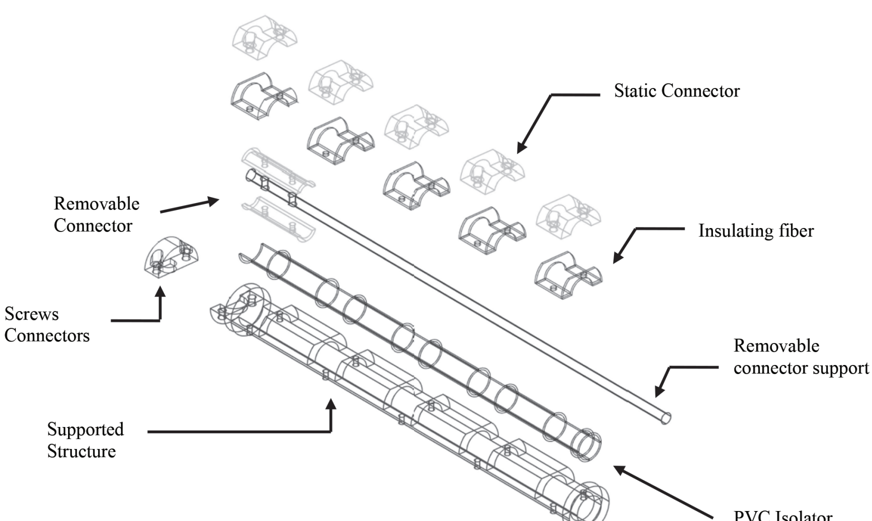

Figure 10. Classical RDM Sensor 3D designed

Figure 11 shows the characteristics of the Classic RDM sensor, the ohmic output resistance is proportional to the displacement. As a result of the displacement of the moving connector, different sections of the circuit will be connected and consequently, the output resistance will follow this movement. It is noticed that in the switching zones when the moving connector is connected to two static connectors at the same time, the output resistance has a decrease (determined by their equivalent resistance).

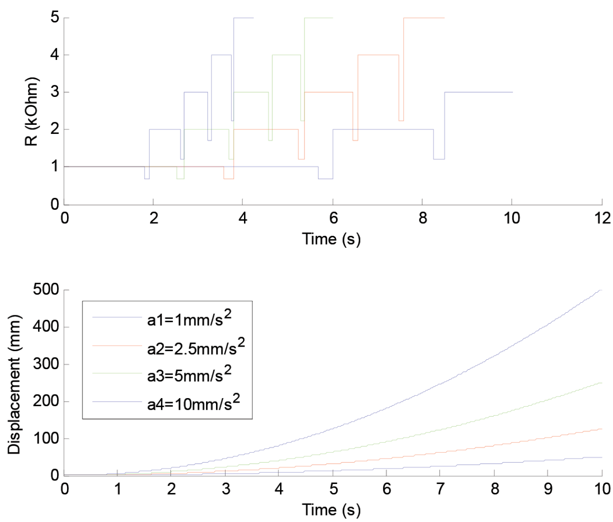

Figure 11. Classic RDM sensor Characteristics

3.2 Railway system monitoring

For the monitoring of the railway system, the RDM sensor will be placed between two metal rails and will measure the distance between them. If as a result of the earthquake the rails are damaged the alarm system will notify the locomotive driver to act to avoid the accident. It is recommended that ultrasonic RDM sensors be used in these systems to achieve more satisfactory results accuracy.

4 Conclusions

Through this alarm system, we can monitor in real-time the bridges and the road system to guarantee the safety of their operation. This system will help emergency structures to act more quickly in assisting with information on damaged axes is provided in real-time. The implementation of this technology significantly increases the safety of roads and bridges and prevents railway accidents that can be caused by earthquake damage on the railway line. The sensors presented in this paper are designed and manufactured in Albania and have undergone laboratory tests to guarantee measurement accuracy. The system can output the results of the ascertainment acts in a few seconds after the seismic shock thus avoiding the overloaded damage ascertainment processes.

Acknowledgements

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