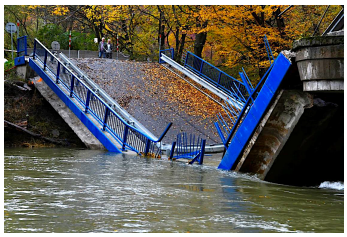
Remote long-term preventive monitoring of bridge failures



Current state and its limits

A high number of bridges are currently in **some state of disrepair**. Their manual monitoring today requires:

- frequent presence of professional staff for visual inspection
- accessibility techniques, recurring restrictions on operation during inspections

The interval between the development of cracks and severe damage or collapse of the structure can be much shorter than between routine or major bridge inspections. This can have fatal **consequences, both in terms of safety and the difficulty of repair**.

Future state and its potential benefits

The key capability is to **detect deepening structural integrity breaches early and quickly**, preferably within seconds or minutes, at low diagnostic costs. An option is to deploy low-cost electronic detection and communication technology that enables:

- **send a message** to the bridge administrator (email, SMS, etc.) **at the moment of detection**
- measure and provide data at regular intervals for **several years without on-site service**
- be easy to install and low cost to operate
- help determine the appropriate time to deploy costly diagnostics

Solution direction

Today's Internet of Things (IoT) technologies enable mechanisms that were previously unavailable:

- **low-power diagnostic and communication devices** operating with extremely low total energy requirements, i.e. battery life of several years without replacement
- **LPWAN** wireless communication networks tailored specifically for the low-power mode of these devices (e.g. SIGFOX or NB-IoT), which have nationwide availability in the most countries.
- sufficiently **simple and inexpensive early warning diagnostic devices,** enabling mass deployment.

In cooperation with the operations department of the **Road and Motorway Directorate of the Czech Republic**, SmartImp has developed and deployed two types of devices for on-line diagnostics of early warning of bridge structures (mainly of prestressed concrete), which have been installed on several bridges of motorways and class I roads.

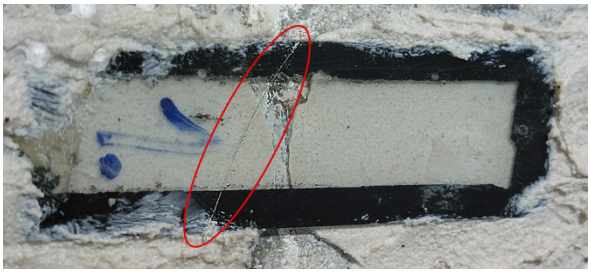
SmartImp s.r.o. (Ltd.) is a company that specializes in the field of construction, industry and energy in the development and production of low-power IoT communication devices with built-in sensors or control of external sensors or data interfaces to sensors.

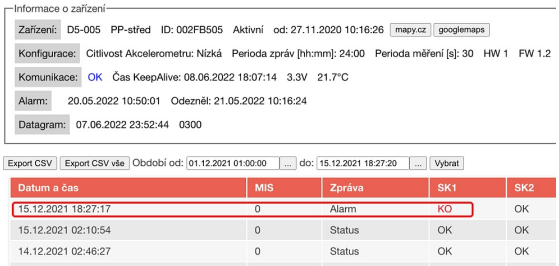
Joint opening detection with SENSECOM-SK

The SENSECOM-SK is a simple device used to detect gap opening from **microcrack** size **50µm.** The device uses commonly used detection glass slides, modified for electronic detection. Their modification does not reduce the brittleness of the glass itself and still allows optical inspection of the cracks/integrity of the glass in a standard way. One or two detection slides, and possibly a thermistor, are connected to one communication device. The device thus allows the bridge manager to be informed immediately, typically within one minute of a crack appearing on a glass slide, or of the active opening of a joint in the bridge structure (or other similar structures).

Experience of deployment on bridges

Already within the pilot project, a crack was successfully detected on one of the monitored motorway bridges in The Czech Republic. It was documented by the RDS bridge administrator after a follow-up inspection. The detection element must be installed using a special adhesive at





Informace o zařízení

Zařízení: D5-005 PP-střed ID: 002FB505 Aktivní od: 27.11.2020 10:16:26 mapy.cz googlemaps

Konfigurace: Citlivost Akcelerometru: Nízká Perioda zpráv [hh:mm]: 24:00 Perioda měření [s]: 30 HW 1 FW 1.2

Komunikace: OK Čas KeepAlive: 08.06.2022 18:07:14 3.3V 21.7°C

Alarm: 20.05.2022 10:50:01 Odezněl: 21.05.2022 10:16:24

Datagram: 07.06.2022 23:52:44 0300

Export CSV | Export CSV vše | Období od: 01.12.2021 01:00:00 ... do: 15.12.2021 18:27:20 ... | Vybrat

Datum a čas	MIS	Zpráva	SK1	SK2
15.12.2021 18:27:17	0	Alarm	KO	OK
15.12.2021 02:10:54	0	Status	OK	OK
14.12.2021 02:46:27	0	Status	OK	OK

SmartImp s.r.o.
Antala Staška 455/64, 140 00 Prague 4, Czech Republic
http://www.smartimp.com/

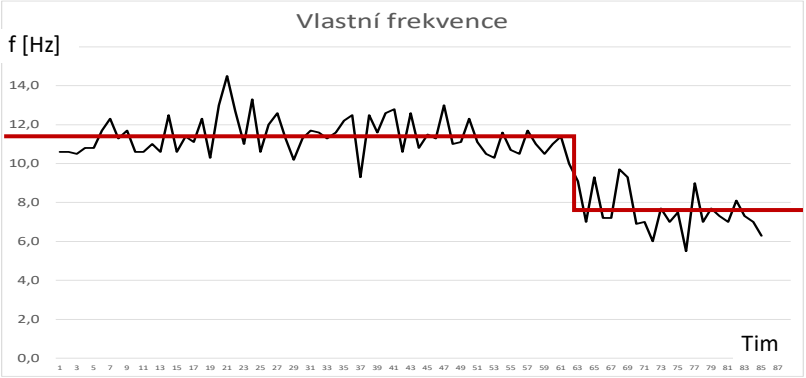
the point where the crack may occur first, typically at the contact joint of split prestressed beams where expansion joints or cracks are not permitted.

On another of the monitored bridges, the behaviour of 3 detection units was tested during a planned demolition, where a failure was detected almost simultaneously with the bridge collapse. Two of the units detected the gap opening during the collapse, the third only when the unit was retrieved from the rubble.

Detailed information from the deployment of these detection devices is available in **the proceedings of the BRIDGES 2022 conference at BRNO, CZ, pp. 165-169** Ing. Jan Hromádko from ŘSD ČR, Operations Department Directorate.

Bridge rigidity change detection with SENSECOM-NFQ

The SENSECOM-NFQ communication device is developed for the purpose of indicating changes in the rigidity of a bridge structure (early warnings and suspected changes). The detection part of the device continuously senses the frequencies of vibrations of the bridge structure induced by normal freight traffic and evaluates the frequencies of the steady-state natural vibrations in a selected direction, or eventually independently. A steady decrease in natural frequency of oscillations **indicates a reduction in the rigidity of the structure and thus indicates a hidden failure of the structure** (e.g. a decrease in prestressing force or concrete undercutting in the compressed section of the concrete).



Bridge administrators are thus alerted when rigidity changes are detected, **long before the cause of the rigidity change is visible** during routine inspections or diagnostically (destructively or non-destructively) detectable, e.g. by documenting joint opening cracks. This indicative warning is usually a good trigger for inspecting and organizing a dynamic diagnostic or probing of the bridge structure. The findings from a pilot of this type of device will be made available to interested parties soon.

Communication device for precision VW or analogue and digital sensors

SmartImp manufactures other types of communication devices suitable for diagnostics.

SENSECOM-HP series of communication devices have electronics that control **1-5 probes using a vibrating wire (VW)** measurement method. The device is capable of taking measurements at regular intervals (typically twice a day) on precision VW-type sensors (e.g. changes in length, pressures, inclinations, etc.) and sending data for several years without changing the battery and without the need for an operator. The design manager receives an alarm by email or SMS when set values are exceeded. North Bohemian Mines in The Czech Republic has been using these devices for more than 4 years to measure water levels in more than 200 boreholes.

SENSECOM-ANC communication devices with voltage or potentiometer inputs for measuring **1-3 analogue probes** (measurements on common analogue probes, e.g. temperature, displacement and expansion, etc.) work in a similar way. **SENSECOM-CMD** series communication devices are used for sensors with **RS485 or RS232** data interface with **MODBUS** protocol.

Conclusion

Newly built full-area wireless **LPWAN** telecommunication networks (e.g., **SIGFOX** or **NB-IoT**) enable long-term deployment of low-power measurement and communication equipment in the field. These devices are capable of operating for **5-15 years without battery replacement** and without additional operators. The devices measure critical parameters at regular intervals and immediately **notify the operator (email or SMS)** when they change. The operator can also access the measurement history, event management and remote device setup on the portal.

Among the first SmartImp products deployed for bridge structures were devices designed for:

- **monitoring of the opening of joints (cracks) in bridge structures** by means of detection slides with electronics and remote transmission (SENSECOM-SK)
- **monitoring of changes in structural rigidity** by means of changes in the natural vibrations of the load-bearing concrete structure of remote-transmission bridges (SENSECOM-NFQ).

The monitoring of gap opening has been running for 2 years on several bridges of motorways and class I roads. In one case, a crack has already been successfully detected. The equipment has also been tested under the special conditions of a planned bridge demolition. Structural rigidity monitoring has been in test and pilot mode for several months.