Results from the building use case being implemented in InComEss

Within InComEss project, Focchi provided the building use case to demonstrate the feasibility of integrating InComEss architecture in a building envelope. Specifically, Focchi designed and validated the integration of Piezoelectric Energy Harvesting Systems (PE-EHS) in building envelopes for powering Fiber Bragg Grating (FBG) sensors, enabling efficient and low-consumption monitoring with the objective to leverage Structural Health Monitoring (SHM).

TEST SET-UP

During the InComEss project, all the activities were focused on developing the most optimized configuration of sensors integration with the aim to validate the InComEss architecture within the façade prototype. Indeed, Figure 1 reported the test set-up.

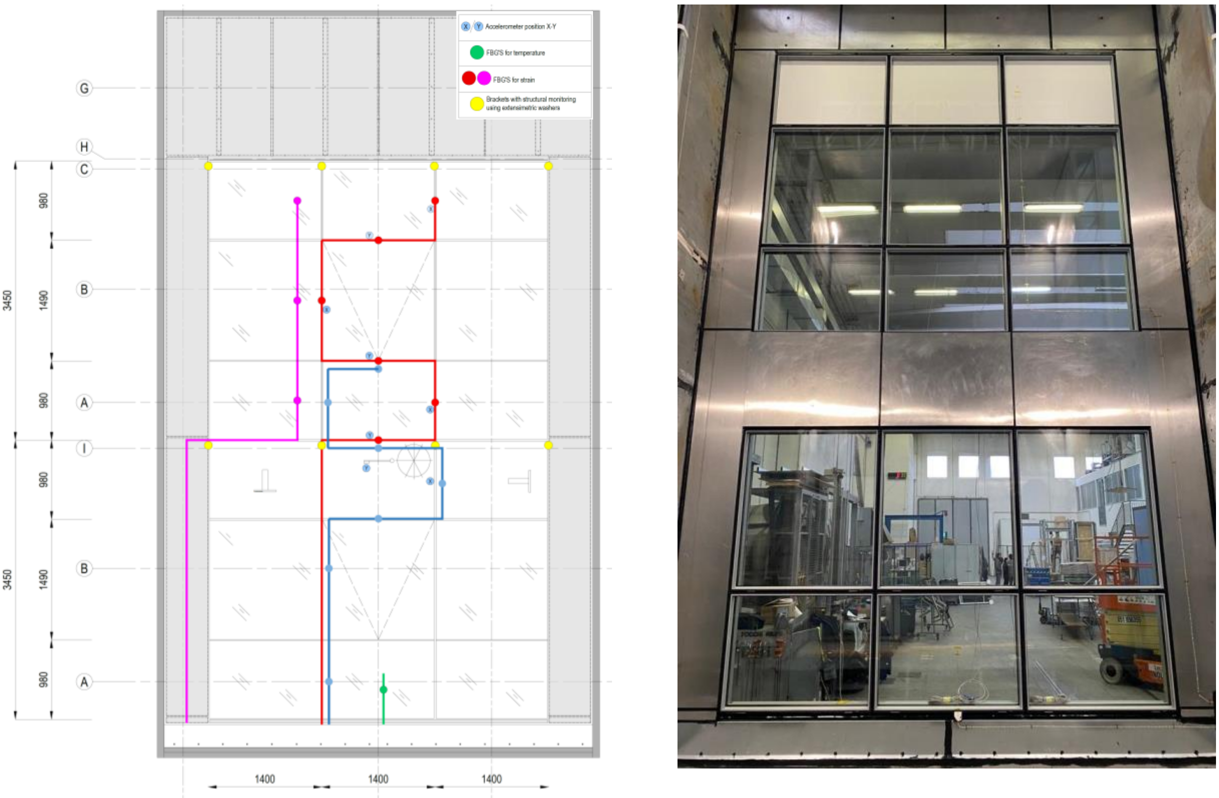

Figure 1 – Sensor's integration within the façade prototype – Test set-up (drawings on the left and pictures on the right)

Table 1. List of data collection system

	Equipment	Monitoring	Data monitoring system	Powered by
Main monitoring system InComEss architecture	**FBG sensors for temperature (1 cable) PE developed within InComEss project.**	**Monitored 1 per time**	**FOS interrogator + gateway + digital platform**	**PE generator and PCB (printed circuit boards) + SC +**
Further structural health monitoring investigation	FBG sensors for strain (3 cable)	Monitored all together	Commercial data collector system supplied by PHOTONFIRST	Commercial electricity
Further energy harvesting investigation	Commercial PE qt. 2	Monitored 1 per time	Data collector system supplied by SMART	Commercial electricity
Contingency monitoring for	Accelerometers qt. 6+1	Monitored all together	Commercial monitoring system	Commercial electricity

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	Equipment	Monitoring	Data monitoring system	Powered by
structural health monitoring	Extensimeter washers qt.8	Monitored all together	Commercial monitoring system	Commercial electricity

Sensor’s integration – the sensors were integrated on-site within the façade prototype. The pictures below show the installation phase.

Figure 2. Wheel configuration integrated within the facade

Figure 3. FBG application of the glass surface

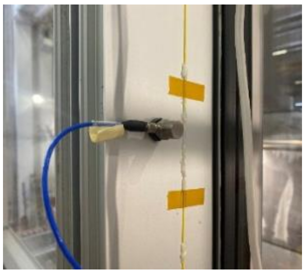

Figure 4. Accelerometers on the aluminum profile together with the FBG

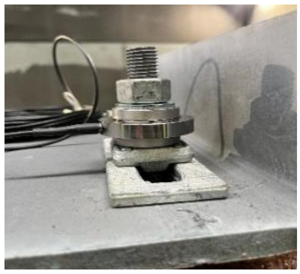

Figure 5. Force washer integration.

Test sequence - The test validates façade behavior and sensor integration for InComEss architecture and conventional sensor kits. Previous phases' outcomes were validated in a lab setting, collecting data from integrated Structural Health Monitoring sensors. Tests under controlled weather conditions included air infiltration, wind pressure, rain, and mechanical stress. Facade performance was monitored in real-time, with data collected for analysis. The pictures below show the façade during the test.

Figure 6. Air infiltration/exfiltration

Figure 7. Rain – Dynamic test

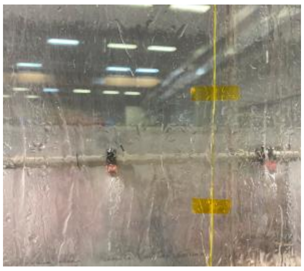

Figure 8. Rain – static test

Figure 9. Impact test – soft body

RESULTS

The result of testing activities outlined the potential of the InComEss architecture in structural health monitoring (SHM) for building applications. Notable results reveal that each InComEss component, assessed individually with standard equipment, worked independently confirming successful recharging by PCC. Indeed, MonadGator tested with external power supply, demonstrating functionality of FBG sensors, Bluetooth Low Energy connection between MonadGator and IoT gateway evaluated, with measured values displayed on gateway's LCD screen, indicating operational BLE connection and 4G connection between gateway and IoT platform also tested and confirmed functional.

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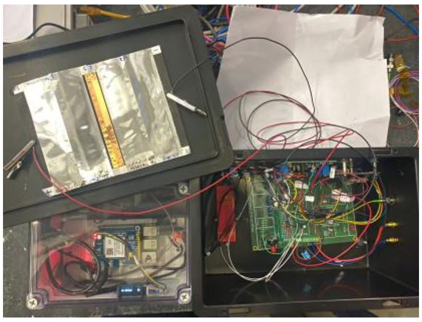
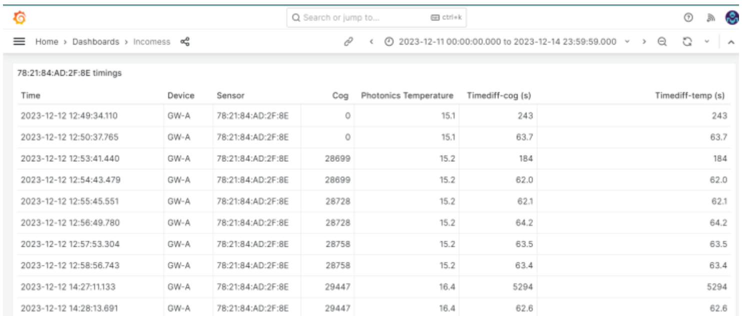


Figure 10. InComEss architecture during the test



Home › Dashboards › Incomess   2023-12-11 00:00:00.000 to 2023-12-14 23:59:59.000

78:21:84:AD:2F:8E timings

Time	Device	Sensor	Cog	Photonics Temperature	Timediff-cog (s)	Timediff-temp (s)
2023-12-12 12:49:34.110	GW-A	78:21:84:AD:2F:8E	0	15.1	243	243
2023-12-12 12:50:37.765	GW-A	78:21:84:AD:2F:8E	0	15.1	63.7	63.7
2023-12-12 12:53:41.440	GW-A	78:21:84:AD:2F:8E	28699	15.2	184	184
2023-12-12 12:54:43.479	GW-A	78:21:84:AD:2F:8E	28699	15.2	62.0	62.0
2023-12-12 12:55:45.551	GW-A	78:21:84:AD:2F:8E	28728	15.2	62.1	62.1
2023-12-12 12:56:49.780	GW-A	78:21:84:AD:2F:8E	28728	15.2	64.2	64.2
2023-12-12 12:57:53.304	GW-A	78:21:84:AD:2F:8E	28758	15.2	63.5	63.5
2023-12-12 12:58:56.743	GW-A	78:21:84:AD:2F:8E	28758	15.2	63.4	63.4
2023-12-12 14:27:11.133	GW-A	78:21:84:AD:2F:8E	29447	16.4	5294	5294
2023-12-12 14:28:13.691	GW-A	78:21:84:AD:2F:8E	29447	16.4	62.6	62.6

Figure 1. Digital platform during the test (the InComEss architecture was powered with commercial energy)

However, issues arise when they are connected, particularly concerning the energy generated by the InComEss power electronics (PE), which was insufficient to sustain the architecture due to significant voltage drop in an open circuit experienced when connected to the PCC and low voltage generated by the InComEss PE-EH.

Energy harvesting - During the test the air pressures refer to an air velocity from 9.03 m/s to 31.30 m/s on the façade. The results of the rain dynamic test are reported since is the most complete one, indeed the façade was stressed by a dynamic forced, rain pressure, pulsation (+750 Pa and 250 Pa every 3 seconds) and dynamic fan which goes up and down twice in each façade modules. As result PE1(commercial PE vertical configuration) reached a peak of 30 V and an average value of 8 V while PE2 (commercial PE horizontal configuration) reached a peak of 10 V and an average value of 6 V.

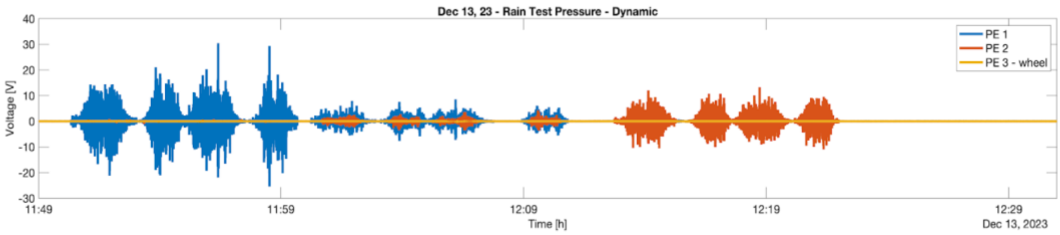


Figure 2 - Zoom of the result of rain - dynamic test - PE

To sum up, during the test configuration 1 (commercial vertical PE position) generated the highest energy value. Despite initial success, the wheel configuration of the InComEss PE exhibited unexpected performance variations compared to preliminary tests, sensitive to wind direction and stability. In lab tests the wheel struggled to rotate at 5-8 m/s, suggesting a need for more stable wind conditions even at lower speeds (<5m/s).

SHM - Integrating FBG sensors and conventional sensors into facade systems presents significant opportunities for building envelope SHM. FBGs offer compact alternatives to conventional sensors like thermocouples, validating temperature measurement within the building envelope. Similar benefits apply to FBGs for strain and vibration sensing, despite some maintenance limitations. Conventional sensors like accelerometers and force washers effectively monitor dynamic and static loads, revealing structural variations and stress responses, particularly in wind-vulnerable areas. The graph below shows the data collected during the second day of testing underlining its effectiveness in building applications.

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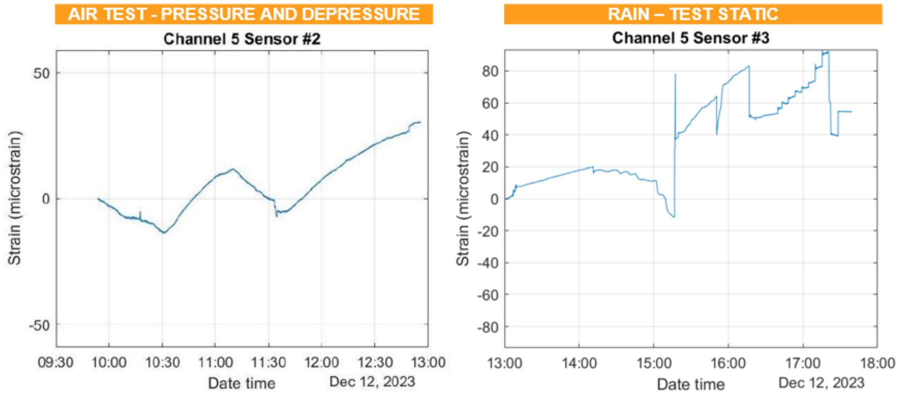

Figure 3. Day 2 FBG for strain – Channel 2-3.

This conclusive project phase validated the efficacy of the InComEss architecture in real-world environmental scenarios showing the potential that these technologies could have on the building sector market, in particular InComEss paving the way for its potential application in structural health monitoring within the building industry. However, further improvement needs to be made. Moving forward, the research proposes several possibilities for further exploration with the aim of bringing the technology close to market. For instance, investigating the application of more piezoelectric elements (PE) to enhance voltage generation.

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Details

Project title: INnovative polymer based COmposite systeMs for high efficient Energy Scavenging and Storage

Project ID: 862597

Start Date: 01/03/2020

Project Duration: 48 months

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