ISSUE
4&5
February
2017

RECONASS Newsletter

Reconstruction and REcovery Planning: Rapid and Continuously Updated COnstruction Damage and Related Needs ASSessment

RECONASS

In this issue

Editorial

Welcome to the 4th/5th newsletter of the RECONASS project.

RECONASS is a European 7th Framework project funded under the SEC programme (grant agreement no. 312718).

The main objectives of the project are (a) to provide a monitoring system for critical buildings that will provide a near real time reliable and continuously updated assessment of the structural condition of the monitored building after a disaster, (b) in case of spatially extended events, e.g., a strong earthquake, to use the above assessment of the monitored facilities for the speedy calibration of satellite and oblique aerial photography of the damaged area and (c) to provide a post-crisis needs assessment tool in regards to construction damage and related needs that will be based on input from (a) and (b) above.

The project officially launched its activities in December 2013. Since then the partners have developed (a) a first prototype of the monitoring system that consists of local positioning tags to determine the position of selected points of the structural system before and after a catastrophe and thus determine the structure that has emerged from the disaster, strain sensors attached to the columns at the ground level to determine the distribution of loads and accelerometers to assess the structural condition under vibrations, e.g., in the case of seismic loading, (b) a methodology and coding for assessment of the status of structural and non-structural elements and (c) a damage methodology for multi-view oblique airborne imagery. Additionally, the partners have successfully performed two separate series of component tests on two structures of different complexity mainly to support the design of the large RECONASS pilot in August, 2016, in which the whole integrated system was demonstrated.

In this issue you will find a description of the pilot test of the integrated system and based on this, the evaluation of the developed sensors, communication system, structural and non-structural modules, remote sensing module and the Tool for Post Crisis Needs Assessment in Regards to Construction Damage and Related Needs, as well as brief description of the project's 2nd end-user workshop in Berlin.

Angelos Amditis, Project Coordinator

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no [312718]

Project facts

DURATION
42 months

TOTAL COST
5,48 million euro

REQUESTED EU CONTRIBUTION
4,26 million euro

The Pilot Test in Sweden

On the 25th and 30th of August 2016, in Älvdalen, Sweden, a large demonstration of the RECONASS system in real conditions was successfully set up to experimentally validate the system's functionality.

In brief, the RECONASS project creates a monitoring system for critical buildings that will provide a near-real time reliable and continuously updated assessment of the structural condition of the monitored building after a disaster. The system uses inputs from in-building sensors; accelerometers, local positioning tags, strain and temperature sensors and the assessment picture is complemented by oblique aerial photography of the damaged building and surrounding area.

The demonstrator concept was basically the instrumentation of a 3 storey building of reinforced concrete, with the RECONASS sensors and prototypes and the execution of massive blasts from its exterior (400 Kg of TNT) and its interior (16 KG of TNT) to evaluate the RECONASS system in a live experiment, as close as possible to realistic conditions.

The RECONASS demonstrator showcased how the RECONASS system as a whole assesses rapidly the structural condition of the monitored building after a disastrous event. Moreover, the behaviour of the individual prototypes has been put into stress (i.e. the sensors and their casings, the communication nodes, the structural assessment algorithms, the UAV assessment process, and the disaster management tool at the service of the end users that visualises the condition of the building post event).

In overall, the demonstrator was proved of outmost success as the system's merits and functionalities have been experimentally validated, revealing at the same time where room for optimisation exists.

Fig. 1 shows the instrumented building with accelerometers (black boxes at the end of slabs), local positioning tags (red boxes at the ends and middle of beams and columns) and temperature sensors (green boxes). Additionally, when the foundation was constructed, strain sensors were installed at the rebars at the bottom part of the columns at the ground level.

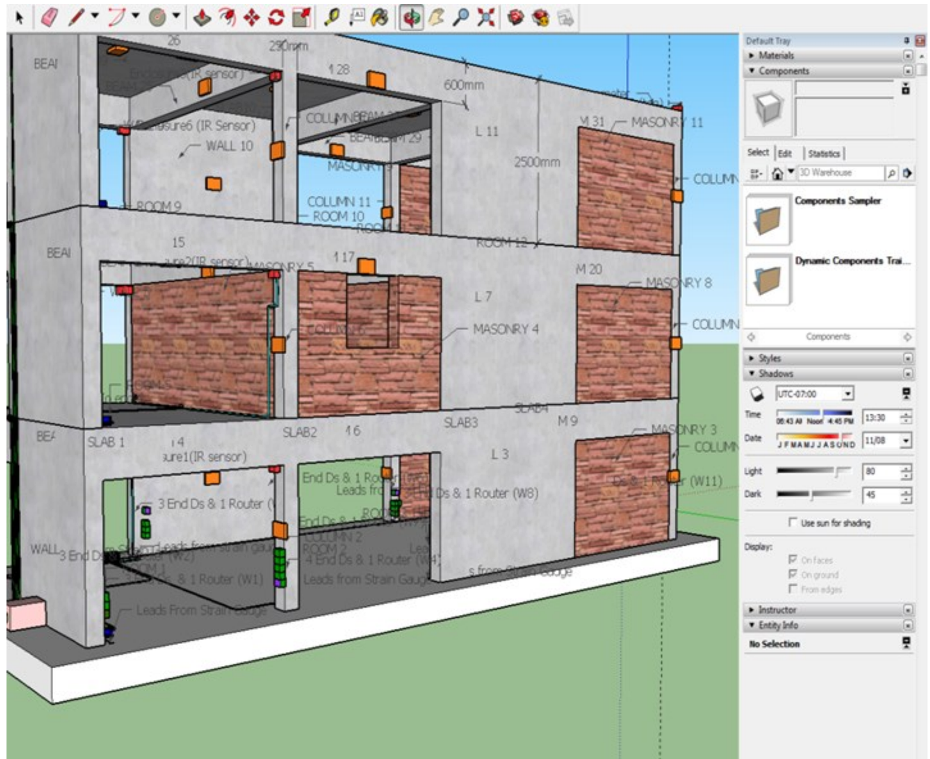


Figure 1. Pilot Design (left) & 3D Representation of the pilot building instrumentation (right)

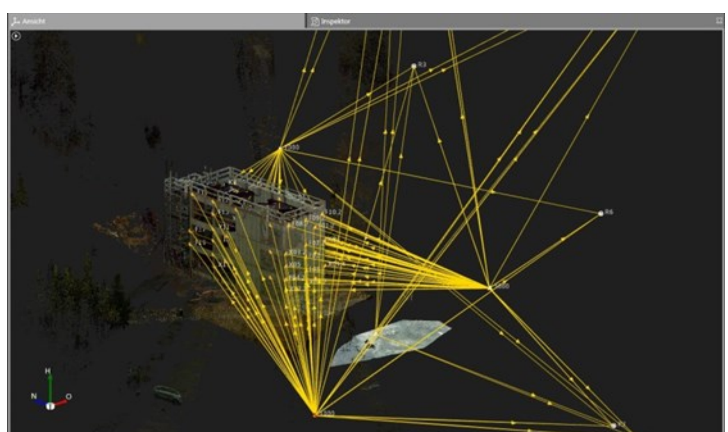


Figure 2. Laser scanning (an additional evaluation metric of the assessment process)

Furthermore, additional instrumentation means have been deployed to assess the system, including: a) A laser scanning/total GPS base station system to measure the building's reactions to blast with mm accuracy (see Fig. 2); and b) high-frequency accelerometers and pressure gauges to measure the pressure wave and the blast impact subjected to the building.

Figure 3. The Pilot Building after the External Blast

On August 25 there was a 400 Kg of TNT external blast, after which the RECONASS system remained operational with minor losses of components that did not affect the assessment process. The image in Fig. 3 depicts the building and the instruments' status. The building remained safe!

Figure 4. Pilot building's condition after internal blast (floor collapsed and external walls/columns were severely displaced)

On August 30 an internal blast with 16 Kg of TNT, was executed which was severe to the building (as anticipated/simulated) and some losses of components occurred. However, the monitoring system remained (partially) operational as, even though individual sensors failed, it was able to provide, via the absence of data from particular sensors, the assessment that the building was not in a structurally safe condition for certain areas.

In overall, the RECONASS Pilot tests have been a very successful conclusion of the research, implementation and integration efforts of the entire consortium. Not only the project's scope (tools and assessment algorithms) was experimentally validated, but the pilot has been a unique experience for benchmarking and validating the system, allowing at the same time to clearly identify where room for optimisation exists.

The Developed Sensors

Sixty five of the packaged local positioning tags were installed on the building's beams and columns before the explosion experiment. Reference measurements were carried out with the tags before the explosion, using data from a total station as ground truth values, to get a snapshot of the building before the explosion, which was working as expected. Furthermore, the partners successfully demonstrated the tracking of the position of a person carrying a mobile Local Positioning System (LPS) using the installed infrastructure.

After the first detonation (large charge outside the building), no LPS measurements were possible at first. All the installed tags were examined, discovering that the provided housing did not give enough protection from the blast, resulting in all stations being damaged except one (which was protected by a special honeycomb box). All tags were then removed and 55 of them were repaired and reinstalled in the building to get the 'after image', which was recorded successfully. Before the second detonation, all LPS tags were removed from the building, since it was now known from the first test, that the provided housings are insufficient and the units certainly will be damaged.

After the second detonation, a subset of the tags was reinstalled in an accessible area of the building and the 'after image' was successfully recorded, showing the deformation of a collapsed ceiling.

Communication Gate

As the RECONASS Project delivers a multifaceted integrated monitoring solution for reinforced concrete buildings, intra & inter--system communications pose a significant challenge towards effectively and securely capturing, processing, transforming and conveying all useful data which – upon proper analysis and representation – indicate the structure's condition. In this context, to handle massive data generated from the monitored building the RECONASS communication module developed in the project comprises of specialised hardware properly fine–tuned and integrated as well as of custom-made in-house software to satisfy monitoring demands and accommodate for any sensors and networks data exchange.

Fig. 5 provides a glance of the communication module's architecture and how the different nodes interconnect with each other.

On a bottom-up approach, the communication module is responsible to enable data reception from the in-building sensors (in RECONASS case, these are strain, temperature, acceleration sensors and local positioning tags but the software and hardware enablers remain functional for any type of sensors). In more detail, all such data are aggregated in 1st tier communication nodes, namely the data hubs which are responsible to capture raw synchronised data and encapsulate them into XML -based files. Temperature and acceleration sensors are transmitting values via analogue cables whereas strain and positioning sensors are wirelessly transmitting data over standardised 802.15.4 interface (ZigBee Pro). The data aggregation and file conversion logic is governed by specialised software which is embedded in the 2nd tier node, namely the RECONASS communication gateway which manages the entirety of transactions between the communicating elements (intra and inter-system). The process described so far refers to the data management layer of the gateway and further to data collection it includes data validation and local storage. Moreover, the gateway implements sensor management functions, enabling a set of semi-automatic tasks in regards to 1st tier devices, be it sensors or network nodes. Such functions include sensor status updates (whether a sensor configured properly), abnormal behavior alerting (when a sensor is failing), user authentication and authorisation (for all sensors joining the network or users accessing network devices), data encryption (for all data exchanged within the established network) and device configuration (change of device set up en operations). The connectivity be-

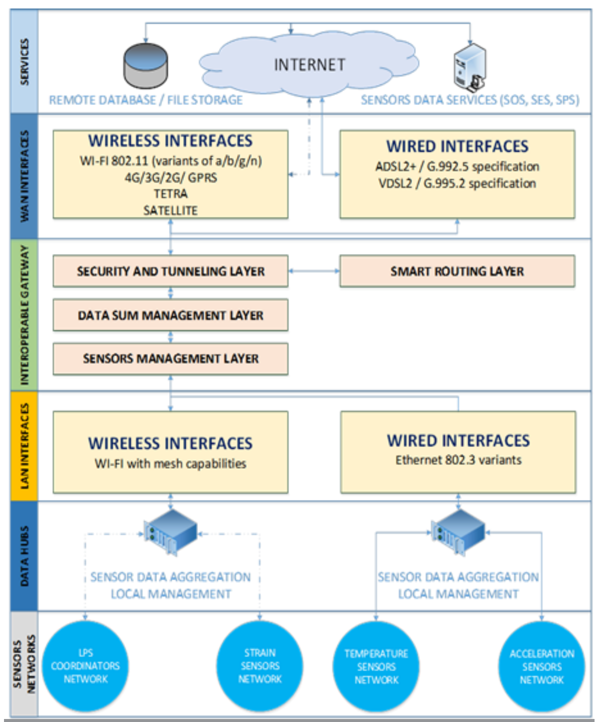


Figure 5. RECONASS Communication Module Architecture

tween 1st and 2nd tier devices (data hubs and gateway) is facilitated by the use of the NetQuake Server, either wirelessly (802.11) or wired (802.3) implementing fail-over capability. Moreover, the sensor management layer is responsible for transforming 1st tier data to OGC-SWE compliant ones to facilitate sensor observation, tasking and alerting services required by the 3rd tier communication as services to remote databases.

3rd tier communication refers to the ability of the gateway to access external platforms or services, thus exchanging data over wide area network (WAN) interfaces; basically, bi-directionally exchanging in-building sensor and device data with remote databases for further processing and/or visualisation. To do so, the gateway implements the security & tunnelling and the smart routing layers. The former is responsible to securely establish a

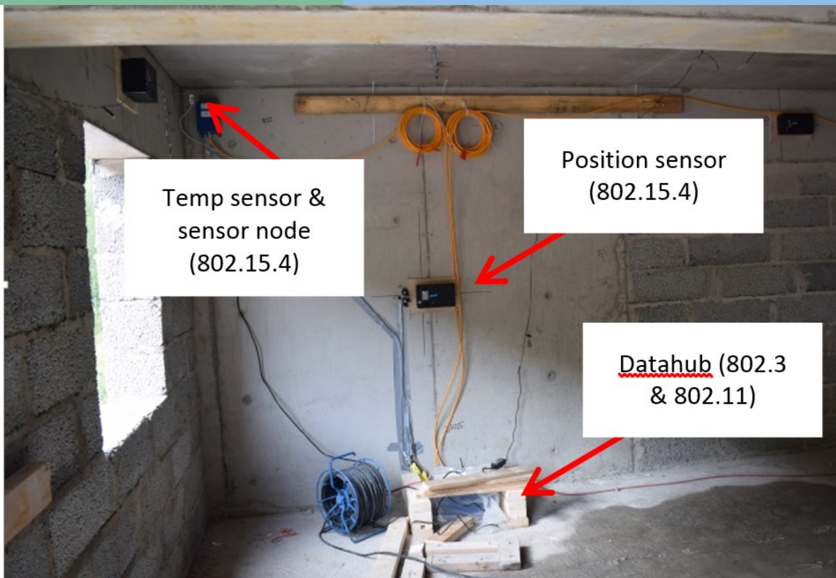


Figure 6. Snapshot of the rack hosting the RECONASS gateway

virtual private network (VPN with use of private keys and certificates) between the hosts (gateway's WAN interfaces) and the remote database as well as to monitor in-building (local) networks' performance and take re-routing actions if necessary. The latter includes customised and adaptive routing protocols (open variants of OLSR and AODV) towards the best utilisation of several IP interfaces (such as mobile networks, satellite and 802.11). Such optimum usage of network resources is also applied by the implementation of the specialised algorithms (adaptation of Weka Algorithm) that combines performance metrics such as link quality, error rate and link sensitivity with data throughput needs. The algorithm exploits the nearest neighbors' principle to route the traffic over the available IP interfaces.

The communication module developed in the RECONASS project governs the entirety of communications among sensor and network nodes within the monitored building or to and from remote databases. This solution has been created to support secure, interoperable and resilient data exchange either in crisis conditions or in normal operations. The data management logic implemented allows for future extensions of the system, as it is capable of hosting any type of sensing device and supporting all-IP data exchange, permitting for the customised hardware and the in-house software to adapt numerous monitoring applications across several domains.

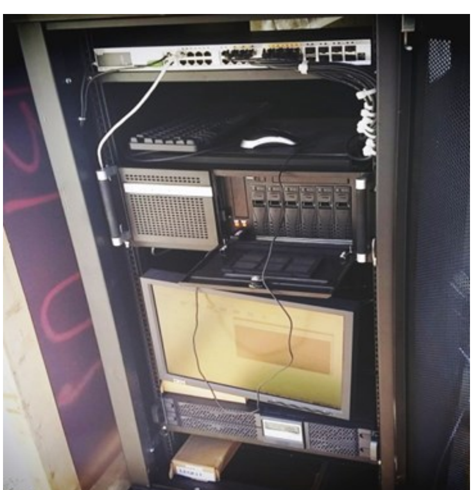


Figure 7. Snapshot of in-building installation

Brief Post-Pilot Report

For the pilot's scope, concerning a 3-storey structure, the communication module embedded the full set of functionalities (from the software perspective) and a basic hardware configuration to support the exact number of sensors, network devices and access means to external databases that were deployed in the pilot site. As the pilot tests concerned two consecutive explosions (an external and an internal one), whereas idle times existed in between, the communication module has been fully operational during a timeslot of two hour, starting one prior and ending one after the explosion event.

Within these intervals the communication module captured and processed approximately 5 million of sensor values (per explosion) and managed a total of 130 sensors and 65 network nodes (ZigBee Pro nodes, network switch and data hubs). These measurements and the device-related data have been transmitted to the remote database of the PCCDN tool (RECONASS' disaster management platform) over dedicated LAN interfaces.

For the first test and in terms of performance, the totality of in-building data belonging in the 2 hour slot have been captured, processed and transmitted to the remote database, error and loss-free, in approx. 4 hours. This 0.5 transmission performance ratio was caused due to the large amount of interconnected sensors providing heterogeneous data simultaneously, thus forcing the software to underperform (failing threads due to memory capacity reached). For the second test and after exhaustive troubleshooting real time data transmission was achieved. An additional instance was created in the communication module that processed and transmitted the various data in large bunches (parallel processing) of several thousands of measurements instantaneously.

As a conclusion the communication solution prototyped in the RECONASS project has been successfully tested in close to realistic conditions (pilot-experiment, see figures below) to prove its usefulness, effectiveness and efficiency in building monitoring applications. Nonetheless, the communication tools and software developed can be utilised in different applications of various domains (security, transport, logistics, health, environment, etc.) that involve sensor-based monitoring.

The Structural Assessment Module

The first explosion was executed on the surrounding area of the structure with the detonation of 400 kg of explosive material at a distance of 13 m from the narrow side of the building. The effect of this outside explosion to the structural members of the building was of an insignificant magnitude with a maximum displacement of the directly affected load bearing walls of less than 3 cms at the midpoint between bottom and top slabs at the ground floor where it also presented horizontal cracks, with even smaller displacements and less pronounced cracks at the higher storeys. The non-load bearing brick wall at the ground floor on the side directly affected by the explosion was demolished and fragments were thrown towards the inside of the building causing minor damages to other non-load bearing elements, whereas in the first storey, the corresponding wall only partially collapsed and on the top floor only presented minor damages.

The second explosion was executed on the inside of the building with the detonation of 15 kg of explosive material approximately at the center of the first floor of the building. The non-load bearing wall closest to the source of the explosion was demolished completely and its fragments could be later found at a great distance from the building (approximately 20 m away) whereas the load bearing columns on either side remained intact. The load bearing shear wall on the opposite side presented a large displacement of approximately 0,50 m which led to the abruption of the supported connecting beams on both top and bottom slabs of that storey and their collapse towards the inside of the structure. The remaining structural members as well as the top slab on the second storey of the building remained unaffected by the explosion.

Evaluation of the Structural Assessment Tool

1. External Explosion

For the non-linear elastoplastic analysis of the structure after the external explosion the data required are the permanent displacements developed at the nodes of the structural model which are defined at the joints between the structural elements at their end points, as well as at their mid-span points. Because of the diaphragmatic action of the slabs the horizontal displacements at the nodes lying on their level are obtained from the horizontal displacements of two nodes per slab, where 2D accelerometers are installed. The vertical displacements at very location and the horizontal ones at the mid-span points of the columns and shear walls are obtained from the records of tags installed at these nodes.

In the pilot structure four 2D accelerometers, instead of two, were installed at the corners of every slab level, the two superfluous as reserves in the case that some of them were destroyed from the explosion. Nevertheless, out of the 16 accelerometers installed, records were obtained only from four, two at the first and two at the third slab level. Records from the tags have not been received as a number of them were destroyed and for the rest the values of the displacements developed were lower than their limit of accuracy. For the external explosion, where only horizontal displacements were expected to be developed at the nodes, the loss of the tag measurements was not critical for the structural assessment, except for the case of the shear walls at the front side directly exposed in the blast wave.

The structural assessment tool was applied by using the data of the accelerometers' records. The permanent displacements at the four nodes were calculated through a double numerical integration of the accelerograms, after a low pass filter to cancel noise, although the 6 measurements per cycle obtained (the oscillation period measured with a value of 0.012S and 500 measurements per second) offered a limited accuracy for the integration procedure directly from the recorded accelerogram. For a larger multi-storey building, with a higher value of the period of oscillation, and thus an increased number of measurements per cycle, the accuracy of the integration's results without the use of the low pass filter, would be considered as satisfactory. For the accelerograms not recording at the corresponding two nodes on the foundation level and the two nodes at the second slab level, the displacements were estimated manually from a polynomial interpolation between the values of the displacements resulting for the first and the third slab level. The values of the displacements' data obtained are listed in the following table.

Level	Node	Accel-erometer	Displacement	
			δx	δy
±0,00	72		0,011185	0,00532
	67		-0,06101	0,01045
±2,50	42	VS007	0,02450	0,01850
	39	VS005	0,00248	0,00850
±5,00	26		0,05113	0,014855
	23		0,00946	0,00459
±7,50	10	VS016	0,07776	0,02121
	7	VS015	0,01644	0,00368

These values were introduced as imposed displacements in the structural analysis software, where the non-linearity is based on the properties of the plastic hinges calculated to be developed at the end points of the structural members. From the analysis resulted the internal forces at the cross sections of the members and the damage indices at the plastic hinges, which are indicated in Fig. 8.

The results are in agreement with the state of the actual structure at those points, which was observed after the explosion.

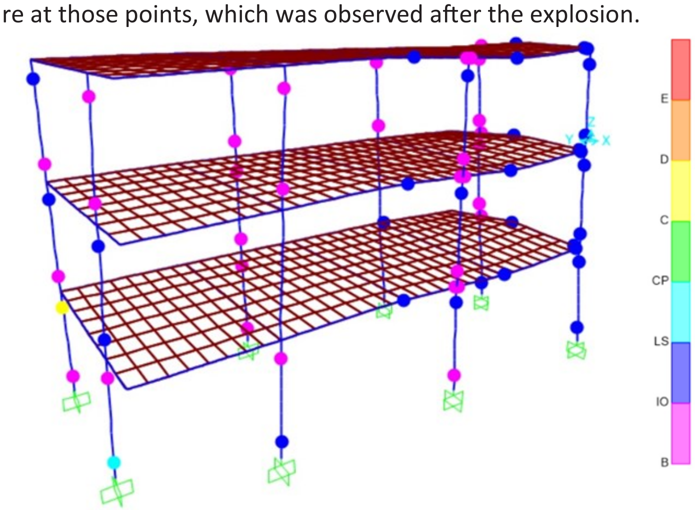


Figure 8 Damage Indices at the Developed Plastic Hinges

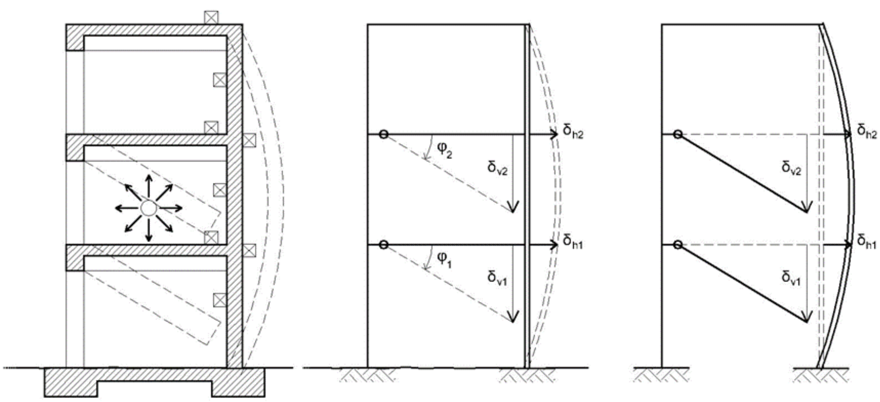


Figure 9 The Pilot Building after the Internal Explosion

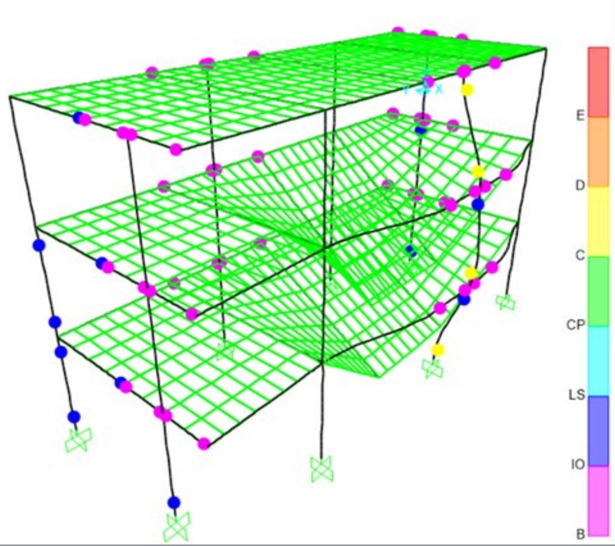


Figure 10 Collapsed Members and Plastic Hinges after the Internal Explosion.

2. Internal Explosion

From the inspection of the pilot structure after the internal explosion, the following important conclusions were reached:

Brittle non-structural elements, i.e. brick / panel / glass walls, directly exposed to the blast load, were instantly blasted into small fragments which were thrown with huge velocities in the form of a stream of mass-missiles striking anything met on their trajectories and spread in the surrounding area.

The void left after the demolition of the separating elements allowed for the dissipation of the blast wave, so that the nude slender columns in the vicinity were not substantially affected by the blast load.

Stiff reinforced concrete elements directly exposed to the explosion with considerable surfaces, i.e. slabs and shear walls, were subjected to huge blast loads leading to the development of big displacements and rotations exceeding the maximum permissible plastic ones, mainly at the connections between the beams and the slabs with the shear walls.

The initial structural model of the building had to be modified according to the LPS measurements, in order to represent the separation between beams, slabs and shear walls and the formation of pin joints, instead of plastic hinges with finite rotations. On the modified structural model a non-linear analysis was executed where the permanent loads and imposed displacements measured from the LPS at the end and the midpoints of the shear walls and those obtained from the accelerometers' records at the rest of the nodes of the model were introduced as actions.

Due to the afore-mentioned observations, the recommended positions for the LPS are at the end- and the mid-span points of the shear walls and at the end-points of the beams and slabs at the positions where they connect to the shear walls. The rest of the LPS tags initially provisioned to be positioned at the midspan points of the beams and the columns, are no longer necessary and can be omitted in future installations.

In the pilot test, useful/accurate LPS measurements were not obtained, as the devices in the vicinity of the explosion were destroyed. The modification of the structural model and the structural assessment had to be based on the surveying measurements obtained after the explosion. The results of the implementation of the structural assessment module are shown in Fig. 10, where the collapsed members and the formation of plastic hinges coincide with those observed at the test site.

The Loss and Needs Assessment Module

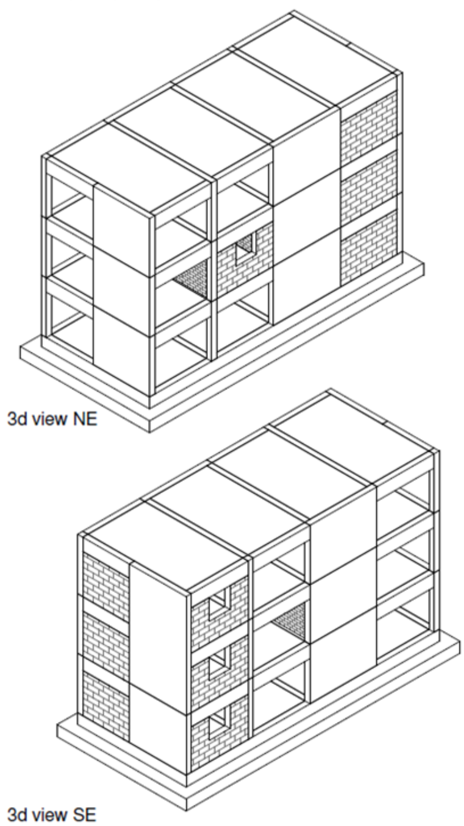


Figure 11 Non-Structural Components in the Pilot Building

The Loss and Needs Assessment Module estimates economic loss and needs taking into consideration the structural response of the building and the conditions of the structural and non-structural components as they are emerging after the event. Calculations take into account the damage states of the building elements, determined based on the damage index or safety factor estimated in the RECONASS Structural Model. Calculations also take into account the damage of the non-structural elements based on relevant parameters from the adjacent structural elements, such as interstory drift or peak floor acceleration, received as input from the Structural Model.

The Non-structural module is the Module including the algorithms for the calculation of the Damage State of the non-structural elements, as well as the relevant economic losses and needs. It is integrated into the PCCDN tool which manages input and output data.

The pilot building includes the following non-structural components:

- External hollow concrete block masonry walls closing all the three storeys of the western part of the building (250 mm of thickness).
- External hollow concrete block masonry wall closing the room were the charge for the internal explosion was located (250 mm of thickness).
- Internal hollow concrete block wall closing the room were the charge for the internal explosion was located (150 mm of thickness).

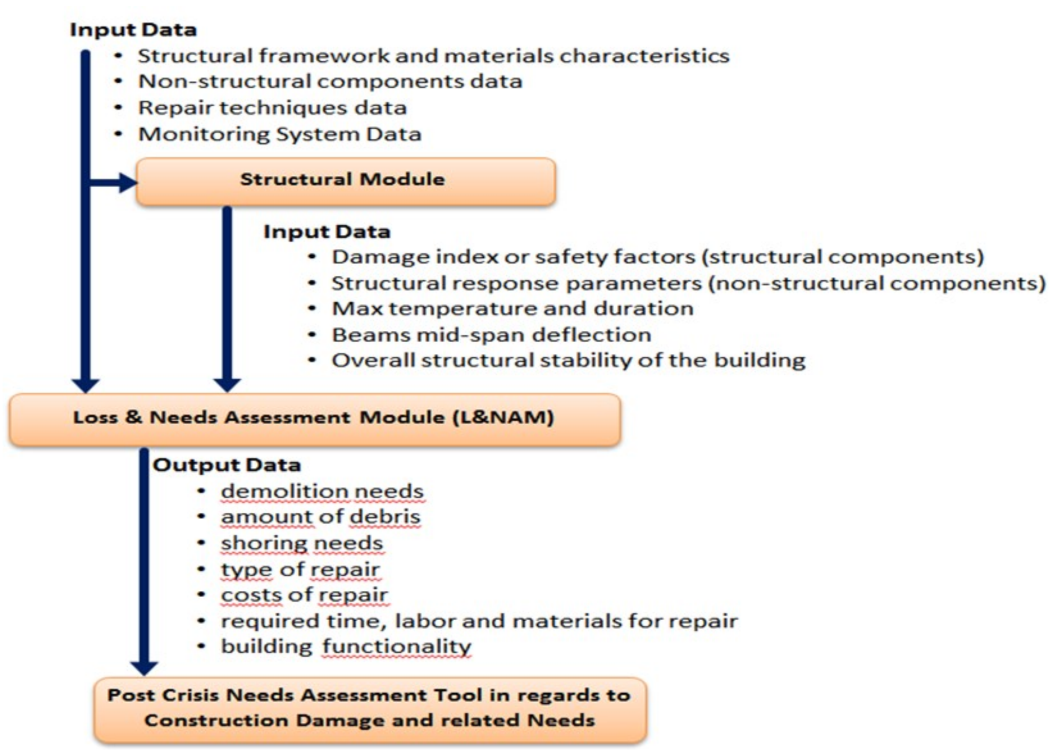


Figure 12 Input and Output in the Loss and Needs Assessment Module

Considering the above non-structural elements, the main functionality to be tested in this module was the evaluation of the damage state following the external blast which included:

- Visual inspection of the pilot building after the test in order to evaluate and survey the damages on the non-structural components of the pilot;
- Analysis of the Damage States calculated by the Module and comparison with the surveyed damaged.

Fig. 13 shows the damages after the blast and the damages states calculated by the Module as described in the taxonomy which they are in good agreement.

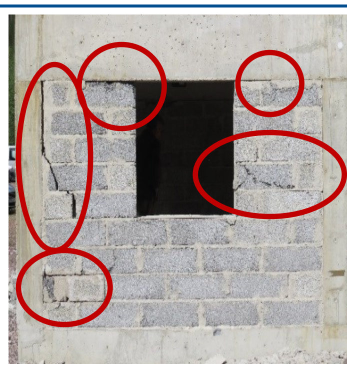
storey	**BEFORE THE BLAST**	**AFTER THE BLAST**	**DAMAGE STATE Calculated in the Module as described in the taxonomy**	**DAMAGE STATE RECONASS RESULT**
3			DS B2011.001.2 - MODERATE Cracks in mortar and wall finishes	DS B2011.001.3 - INTENSIVE Repair action: Some parts of the wall may need demolition and reconstruction. Also the damaged area needs the repair of exterior finish Functionality Level: Partially functioning Debris : 0,56 m^3
2			DS B2011.001.3 - INTENSIVE Severe cracks in the wall (X-diagonal shear cracks) and spalling of wall finishes	DS B2011.001.3 - INTENSIVE Repair action: Some parts of the wall may need demolition and reconstruction. Also the damaged area needs the repair of exterior finish Functionality Level: Partially functioning Debris : 0,56 m^3
1			DS B2011.001.3 - INTENSIVE Severe cracks in the wall (X-diagonal shear cracks) and spalling of wall finishes	DS B2011.001.3 - INTENSIVE Repair action: Some parts of the wall may need demolition and reconstruction. Also the damaged area needs the repair of exterior finish Functionality Level: Partially functioning Debris : 0,56 m^3

Figure 13 Actual and Calculated Damages in Non-Structural Components after the External Blast

The Tool for Post Crisis Needs Assessment in Regards to Construction Damage and Related Needs (PCCDN)

The PCCDN is a Security Platform. With this, crisis managers during emergency events, but also in normal operations, are provided with the continuously updated status of monitored structures and with information about an area upon which they can react. It combines information from various, disparate sources in order to improve the added value of the provided service to the recovery stakeholders:

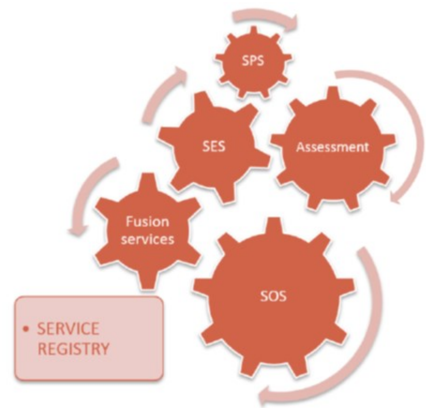
from the wireless sensors (strain, accelerometers, positioning tags and temperature sensors) of the monitored structure,

- from the monitoring–based structural assessment module on the damage state of the structural elements and the overall structure,
- from the damage, loss and needs assessment module on repair needs, debris and functionality in the case of non-structural components,
- from the remote sensing based structural damage assessment module on collapsed and intact buildings in the scene, presence of damage evidences, debris and rubble piles around the building,
- from external sources, such as input from disaster agencies, and meteorological data.

To allow the smooth integration of all these disparate information into the system, the underlying software architecture is SOA (Service Oriented Architecture) where distributed communication through web services is used. Services are published in a service inventory and are orchestrated to provide situation assessment.

The services that are present in the inventory of the PCCDN tool include sensor data services, sensor data fusion services and assessment services. Sensor data services include Sensor Observation Services (SOS), Sensor Event Services (SES) and Sensor Planning Services (SPS). SOS, SES and SPS are coupled together to allow the registration, discovery and access of heterogeneous and distributed sensors. In an effort to clarify the use of services and make integration of sensors quicker and more cost efficient, the provided sensor services comply with the Open Geospatial Consortium (OGC) standards. The Open Geospatial Consortium (OGC) is an international consortium that develops publicly available standards. Through these standards, applications and services can access sensors of all types.

Intelligent data fusion algorithms exploit data from multiple sensor types and locations and dedicated applications de-



tect specific threat types in near real-time and create the input dataset for the assessment modules of the PCCDN to support decision making. The assessment services allow the integration of the assessment modules' information into the PCCDN. The presence of all services in an inventory allows fast and reliable communication and interoperability among diverse applications with minimal human oversight. The services are orchestrated to create high level processed data suitable for visualization and situation assessment for the monitored facilities. All the information is available to the end users though a generic database application which is used as a web-based application, implemented in JAVA/GWT and deployed on Apache Tomcat. Google maps are used to depict information of a monitored area and different layers include information on hospitals, police stations, fire station and assessed debris. Smooth integration between the system modules and sharing of information between the professionals involved in the project (civil engineers, architects, remote sensing engineers, constructors and rescue teams) is ensured with the use of Building Information Modelling (BIM).

The tool complies with specific end-user requirements, including economics, convenience, exportability, efficiency and reliability. The platform's modular nature allows the integration of many sensor types and assessment modules with minimal impact, cost and effort. The implemented environment, using multiple enterprise services buses, ensures reliable performance under stressed conditions. Security measures have been applied to ensure the safe use of services and protection of data within the PCCDN tool.

During the pilot test of RECONASS in Alvdalen, Sweden, the PCCDN tool was tested under real-time conditions. The remote location of the pilot test did not support internet access, so a wired network connection was setup. The PCCDN tool was placed in a bunker that was located 250 m from the pilot building and an Ethernet cable was connecting it to the gateway that gathered the sensor data. After the explosions, the sensor data were smoothly inserted into the PCCDN tool and the assessment algorithms calculated the building situation. Figs 14 and 15 below present the structure colored according to the assessed damage of its elements. Fig. 16 is an example chart of the acceleration recorded during the internal explosion. The PCCDN tool was stable. The results of both explosions were used as an example to enhance the performance of the system and to improve the fusion services.

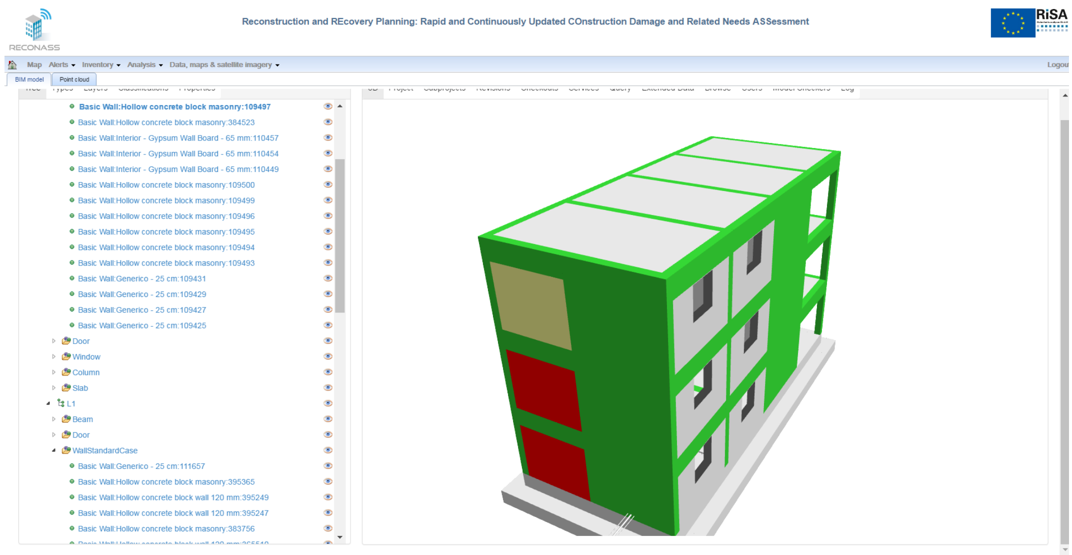


Figure 14 PCCDN visualization of the results after the first explosion .

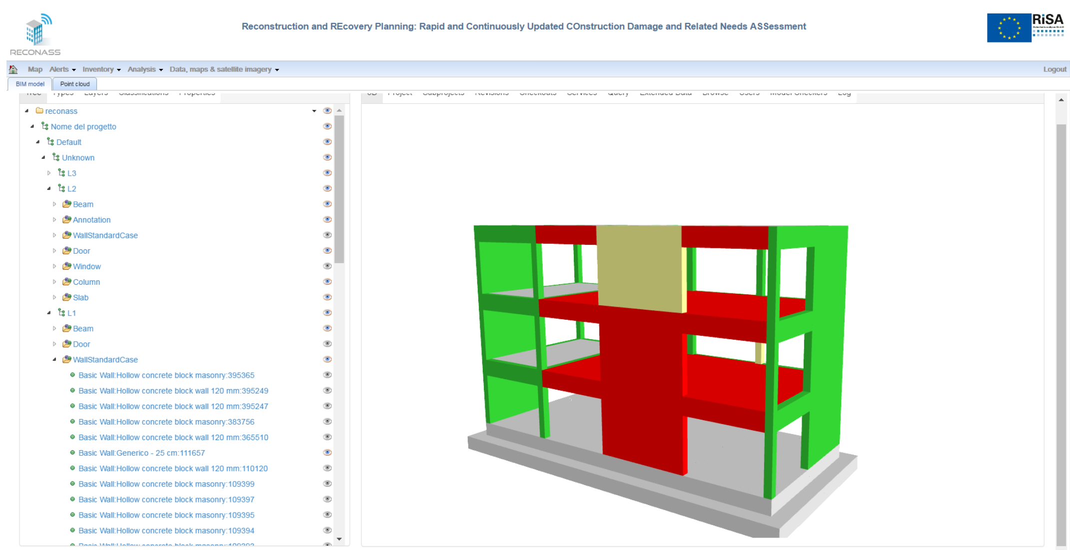


Figure 15 PCCDN Tool Results after 2nd Explosion (combination of manual/automatic/aerial data)

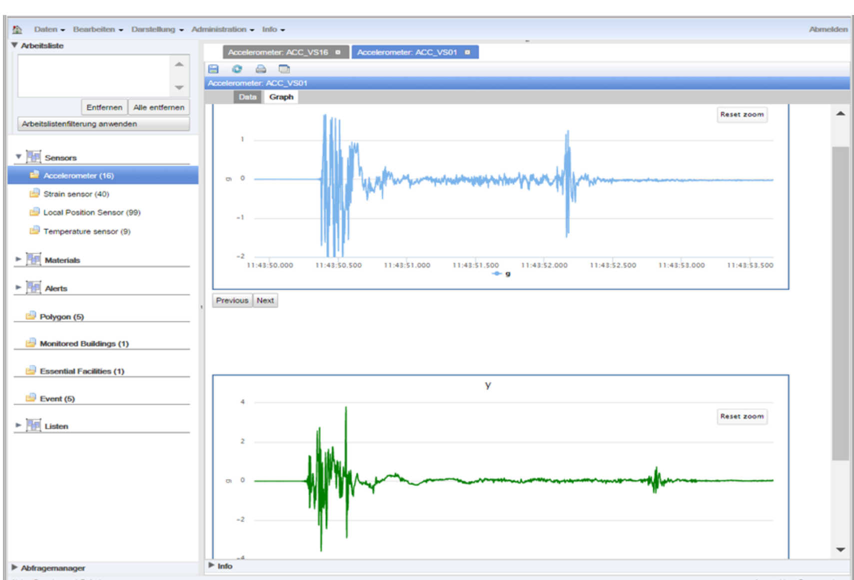


Figure 16 Chart of the acceleration recorded during the internal explosion

Damage assessment using the remote sensing subsystem

Figure 17 Aibotix Aibot X6 V2 (left), and circular layout of images (right).

Remote sensing-based structural damage assessment is one of the subsystems of the RECONASS system. The primary functionality of this sub-system is to perform a detailed damage assessment along exterior elements of the monitored RECONASS- and neighbouring-buildings using the images captured by our own Unmanned Aerial Vehicle (UAV/drone). To this end, several modules have been developed within the subsystem, including 1) data acquisition and pre-processing, and 2) automated damage detection and classification. These modules were evaluated using the data from the pilot experiments conducted on the monitored building constructed in Sweden. The description about the modules and their results are reported below.

Data acquisition and re-processing:

The images were captured using an Aibotix Aibot X6 V2 UAV (Fig. 17) with an average ground sampling distance (GSD, pixel size at the object) of 1.5 cm. In total 103 images were captured. The acquisition went quite smoothly – the circles were flown within 4 minutes (cf. Fig. 17). The captured images were copied to a laptop computer and the so -called image orientation and calibration was performed. Subsequently, the 3D point cloud was generated, which is the input for the damage assessment module.

Automated damage detection process

The damages to the monitored building were automatically identified using the methods in RECONASS, by comparing the post-event 3D point cloud generated from UAV images to the externally visible elements of the CAD model of the monitored building. This assessment included the identification of various damage evidences, and thereby classifying the building elements into different classes, as described below.

1) **Broken elements**: Missing CAD elements in the post-event point cloud were identified by performing the element-wise comparison of the post-event point cloud with the point cloud generated based on the CAD model.
2) **Inclined elements**: The difference in angle of the plane normal for the corresponding planar elements in both the post-event point cloud and CAD model was computed. If the angle difference was greater than a certain threshold (3 degrees), the respective planar element was classified as inclined.
3) **Debris**: The debris and spalling regions were identified based on recognizing the unusual radiometric using information from images based on the method developed within RECONASS. The presence of these patterns on the ground surface was considered as debris, and its volume was quantified.
4) **Cracks**: Cracks were identified based on the radiometric characteristics and geometrical shapes. For example, darker regions with linear shapes on intact planar segment were classified as cracks.
5) **Intact**: The elements with no above mentioned damage evidences were classified as intact.
6) **Occluded**: The CAD model elements invisible in the images are identified and labelled as occluded.

UAV images, point clouds derived from these images, and 3D points of the CAD model were the inputs for this subsystem, and it outputs the classified 3D points of the CAD model, as depicted in Fig. 18.

The classified point cloud of a CAD model representing the damage information (automatically identified by this subsystem), along with corresponding image, are provided in Fig. 18. The monitored building in Fig. 18 is represented in two different orientations, in such a way that all the sides of the building are visible. The detected damages in point cloud and images are highlighted and annotated using the letters A to H for evaluation, which are briefly described in the next page.

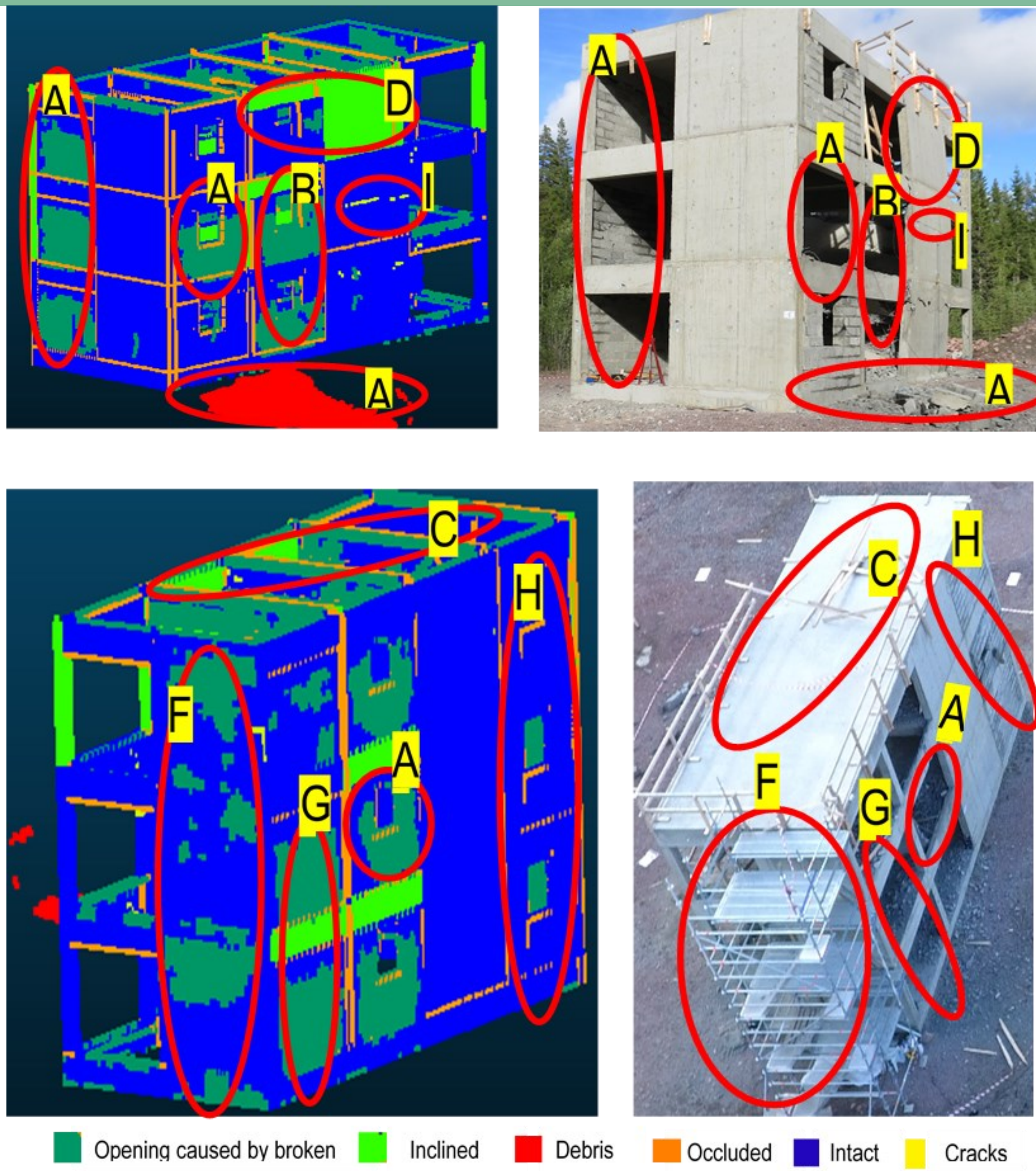


Figure 18 The classified point cloud of CAD model depicting the element-wise damage information (left-top and left bottom) of blast-2, identified automatically by the developed methods, and the corresponding images (right-top and right bottom) for visual inspection. The damaged regions are annotated using letters A-H, which are briefly described in the text.

Damage region A: All broken elements and debris regions were detected by our method.

Damage regions B, F, G and H: These regions were detected as broken elements, since there was a difference in the CAD model and the actual constructed building. For example, the elements in the region B and G in the CAD model correspond to infill walls which are not actually constructed. On the other hand, the building elements corresponding to region F were detected as missing, as they are hidden by the external scaffolding which is not part of the CAD model design. Therefore, these elements in the CAD model were annotated as damage, since they were missing in the post-event point cloud. The developed algorithms worked well for detecting the missing elements, though the reason is not damage. This observation makes clear that in a real case scenario the BIM or CAD model of the building must actually be well maintained and be identical to the as-built-status.

Damage region C: The elements detected as damages in region C were structural elements occluded by the roof. It was not detected as occluded by our algorithm, since they were embedded in the 3D points of the roof segment.

Damage region D: The element annotated as D is correctly identified as inclined, the angle difference between the element in the CAD model and post-event point cloud is estimated as 4.4 degrees.

Damage region I: The presence of a minor crack in this region was identified by our method.

Overall, the developed modules are found to be working well when evaluated using the datasets from the pilot experiments conducted in Sweden. Hence, it is assumed that they can be easily scalable as independent operational sub-system as part of RECONASS system to monitor the real world functioning buildings.

RECONASS 2nd End-User Workshop in Germany

In order to make sure that the development of the RECONASS system is in accordance with practitioners' needs, the Federal Agency for Technical Relief (THW) invited European end users to a workshop on its training grounds in Wesel, Germany.

From the 22nd through the 23rd of June, THW operative personnel, as well fire fighters and ministry representatives from Germany, France, Italy, the Netherlands and Greece had the opportunity to experience a live demonstration of the RECONASS system.

In order to be able to observe the advantages or complementary qualities of the this system, THW presented the mobile construction monitoring system it currently uses. The guest experts were able to ask questions on the spot and were later asked to give feedback on how relevant RECONASS could be for their daily operative work.

The positive workshop results will now be evaluated and implemented in the further development and dissemination of the system.

Scientific Presentations/Publications

E. Sdongos, A. Amditis, "Monitoring Critical Buildings", Article on CRJ, Crisis Response Journal - Protection, Prevention, Preparedness, Response, Resilience, Recovery (Commercial), Issue CRJ 11:2 - December 2015

Mohammed El-Shennawy, Belal Al-Qudsi, Niko Joram, Frank Ellinger, "Fundamental Limitations of Phase Noise on FMCW Radar Precision", 23rd IEEE International Conference on Electronics Circuits and Systems (ICECS) 11-14 December 2016, Monte Carlo, Monaco

Mohammed El-Shennawy, Niko Joram, Frank Ellinger, "A +/-0.15dB Accurate Baseband Detector for FMCW Radars Employing Inherent PVT Cancellation", accepted by IET Circuits, Devices and Systems

S.K. Nammi, G. Edwards and H. Shirvani. (2016). 'Effect of Cell-Size on the Energy Absorption Features of Closed-Cell Aluminum Foams,' Acta Astronautica, Vol. 128, pp. 243-250.

S. Nammi, J.-L. Mauricette, I. Patel and H. Shirvani, 'Stability of Perforated Plates with an In-plane Pre-load on Central Cutout,' Proceedings of the World Congress on Engineering 2016, vol. II, WCE, June 29-July 1, 2016, London, UK.

Follow-up RECONASS

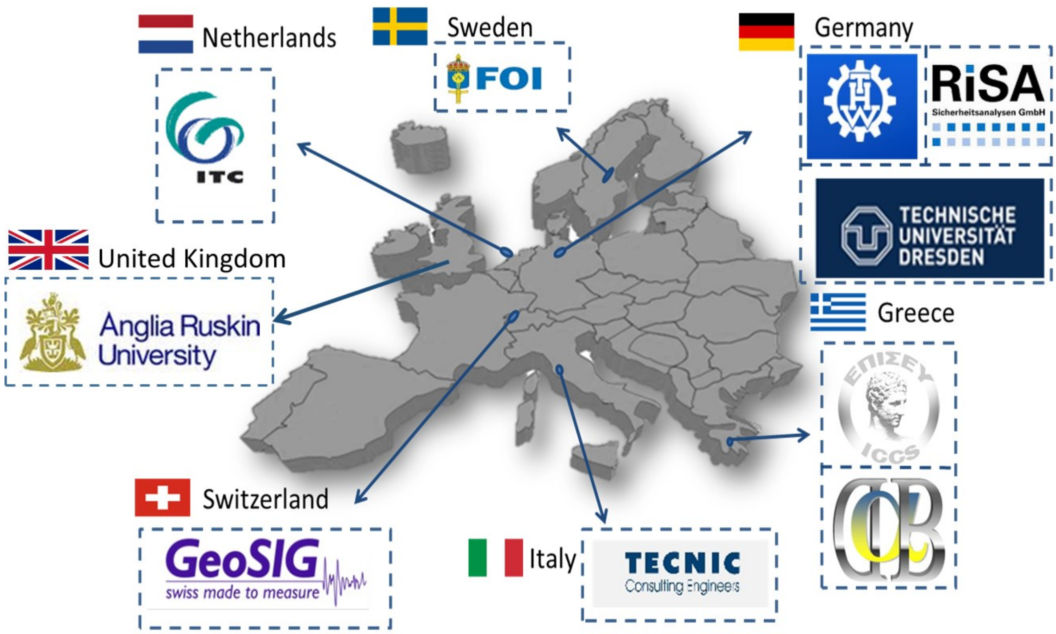
The end user group is invited to follow-up the RECONASS process during the project's lifetime via the RECONASS homepage (www.reconass.eu) as well as via twitter and LinkedIN and to contribute within all in all three RECONASS end-user workshops.

www.reconass.eu

#Reconass

RECONASS group

Consortium



Visit us on the web site at
www.reconass.eu or www.reconass.com

Follow us on Twitter

Join us or RECONASS LinkedIN group

Contact Us

Project Coordinator:
Dr. Angelos Amditis
(a.amditis@iccs.gr)

Dissemination Manager:
Stephanos Camarinopoulos
(s.camarinopoulos@risa.de)