Appendix 3b

Achievements in the field of scientific and research, didactic and organizational activities.

Mikołaj Miśkiewicz, MSc, PhD

Contents

1. Name and surname

Mikołaj Miśkiewicz

2. Diplomas and scientific degrees – with name, place and year of granting, including the title of the PhD thesis

- Doctorate in technical sciences, Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, 2011, title of the thesis: „ Nonlinear before – failure state analysis of the string – rod structures in terms of finite element method”. Tutor: prof. Jacek Chróścielewski. PhD thesis defended with honors
- Master of Science in Bridge Engineering, Gdańsk University of Technology, Faculty of Civil Engineering, 2003, title of the thesis: Study of arch bridge over Saale river in Beesedau. Tutor: prof. Kazimierz Wysiatycki.

3. Information regarding previous employment at scientific units

2015 – now	Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Department of Mechanics of Materials and Structures. Adjunct, the head of bridge laboratory.
2011 – 2015	Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Department of Mechanics and Bridges. Adjunct.
2007 – 2011	Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Department of Mechanics and Bridges. Assistant.
2003 – 2007	Gdańsk University of Technology, Faculty of Civil Engineering, Department of Bridges. Assistant.

4. Indication of the achievement pursuant to Article 16 Paragraph 2 of the Act of 14th March 2003 on Academic Degrees and Title and Degrees and Title in the Arts (Dziennik Ustaw – Official Journal of Laws, No. 65, item 595, as amended)

4.1. Title of the scientific achievement

The series of publications: *Diagnostics of engineering structures, in particular bridges, using innovative in situ measurements and advanced FEM simulations.*

4.2. Publications included in the scientific achievement

1. Miśkiewicz M., Pyrzowski Ł., Wilde K., Chróścielewski J.: Numerical analysis and in situ tests of the Grot Rowecki Bridge in Warsaw. 3rd *Polish Congress of Mechanics* (PCM) / 21st *International Conference on Computer Methods in Mechanics* (CMM), pp. 405÷408, 2016. DOI:10.1201/b20057-87.
   MoSaHE points: 15. My participation is 50%.
2. Miśkiewicz M., Pyrzowski Ł.: Load Tests of the Movable Footbridge over the Port Canal in Ustka. *Proceedings* 2017 *Baltic Geodetic Congress* (*Geomatics*), IEEE, pp. 242÷246, 2017. DOI: 10.1109/BGC.Geomatics.2017.7.
   MoSaHE points: 15. My participation is 60%.

3. Pyrzowski Ł., Miśkiewicz M., Chróścielewski J.: The effect of fishing basin construction on the behavior of a footbridge over the port channel. *Polish Maritime Research*. Vol. 24, nr. S1(93), pp. 182÷187, 2017. DOI:10.1515/pomr-2017-0037.
   MoSaHE points: 20, IF_{2017}=0,763 ($IF_{5\ lat}$=0,816). My participation is 55%.
4. Miśkiewicz M., Daszkiewicz K., Ferenc T., Witkowski W., Chróścielewski J.: Experimental tests and numerical simulations of full scale composite sandwich segment of a foot- and cycle- bridge. 3rd *Polish Congress of Mechanics* (PCM) / 21st *International Conference on Computer Methods in Mechanics* (CMM), pp. 401÷404, 2016.
   MoSaHE points: 15. My participation is 70%.
5. Chróścielewski J., Miśkiewicz M., Pyrzowski Ł., Sobczyk B., Wilde K.: A novel sandwich footbridge. Practical application of laminated composites in bridge design and in situ measurements of static response. *COMPOSITES PART B-ENGINEERING*. Vol. 126, pp. 153÷161, 2017. DOI:10.1016/j.compositesb.2017.06.009.
   MoSaHE points: 45, IF_{2017}=4,920 ($IF_{5\ lat}$=4,858). My participation is 50%.
6. Pyrzowski Ł., Miśkiewicz M., Chróścielewski J., Wilde K.: Load Testing of GFRP Composite U-Shape Footbridge. IOP *Conf. Series: Materials Science and Engineering* 245 032050, 2017. DOI:10.1088/1757-899X/245/3/032050.
   MoSaHE points: 15. My participation is 50%.
7. Miśkiewicz M., Pyrzowski Ł., Chróścielewski J., Wilde K..: Structural Health Monitoring of Composite Shell Footbridge for its Design Validation. 2016 *Baltic Geodetic Congress* (*Geomatics*), IEEE, pp. 228÷233, 2016. DOI:10.1109/BGC.Geomatics.2016.48.
   MoSaHE points: 15. My participation is 50%.
8. Miśkiewicz M., Sobczyk B., Pyrzowski Ł., Chróścielewski J., Wilde K.: Badania odbiorowe obiektu gruntowo-powłokowego rekordowej rozpiętości. *Mosty*, nr 1, s.48÷51, 2018.
   MoSaHE points: 3. My participation is 50%.
9. Chróścielewski J., Miśkiewicz M., Pyrzowski Ł., Wilde K.: Assessment of tensile forces in Sopot Forest Opera membrane by in situ measurements and iterative numerical strategy for inverse problem. *Shell Structures*: *Theory and Applications*. Vol. 3, pp. 499÷502, 2014. DOI: 10.1201/b15684-125.
   MoSaHE points: 15. My participation is 50%.
10. Wilde K., Miśkiewicz M., Chróścielewski J.: SHM System of the Roof Structure of Sports Arena "Olivia". 9th *International Workshop on Structural Health Monitoring* (IWSHM). Vol. II, pp. 1745÷1752, 2013.
    MoSaHE points: 15. My participation is 80%.
11. Miśkiewicz M., Meronk B., Brzozowski T., Wilde K.: Monitoring system of the road embankment. *Baltic Journal of Road and Bridge Engineering*. Vol. 12(4), pp. 218÷224, 2017. DOI:10.3846/bjrbe.2017.27.
    MoSaHE points: 30, IF_{2017}=0,622 ($IF_{5\ lat}$=0,598). My participation is 80%.
12. Miśkiewicz M., Pyrzowski Ł., Wilde K., Mitrosz O.: Technical monitoring system for a new part of Gdańsk Deepwater Container Terminal. *Polish Maritime Research*. Vol. 24, nr. S1(93), pp. 149÷155, 2017. DOI:10.1515/pomr-2017-0033.
    MoSaHE points: 20, IF_{2017}=0,763 ($IF_{5\ lat}$=0,816). My participation is 55%.
13. Miśkiewicz M., Mitrosz O., Brzozowski T.: Preliminary field tests and long-term monitoring as a method of design risk mitigation: a case study of Gdańsk deepwater container terminal. *Polish Maritime Research*. Vol. 24, nr. 3(95), pp. 106÷114, 2017. DOI:10.1515/pomr-2017-0095
    MoSaHE points: 20, IF_{2017}=0,763 ($IF_{5\ lat}$=0,816). My participation is 80%.

4.3. The research scientific aim, discussion and application of results

Diagnostics of engineering structures is a research area that has been developing nowadays very rapidly. It is practiced in many research centres. The reasons why researchers are investigating this field are: large amount of serious damages or failures of structures that have been already built, age of the technical infrastructure and the current tendency to design modern buildings having a complex geometry, characterised with a very high ratio of utilisation level and what is more made of hi-tech materials. Thus, great care needs to be taken in order to verify the correctness of the buildings response in real environmental and operating conditions. Engineers and Researchers strive for better understanding of behaviour of structures. Especially through finding of appropriate theoretical and empirical descriptions that justify the behaviour and are crucial from the point of view of safeness and durability of buildings, also in the context of recycling and the balanced development. The measurement techniques and linear computational analyses, well-established and used for many years, are in most cases sufficient tools to diagnose typical buildings. However, more sophisticated or even unique measurement methods, custom nonlinear numerical models or techniques of analysis at different levels of precision are sometimes required in the case of the analysis of some extraordinary buildings. From this reasons **the Author aim is to establish methodology of diagnostic tests of engineering structures by means of in-situ measurements and advanced FEM simulations**.

Individual diagnostic test programs were prepared for the purpose of detailed analyses of engineering structures (bridges, roofs also flexible membranes, foundation of road embankment – geotechnics, hydraulic engineering) that document the achievements described here. Each created programme has its own consistent method to carry out the necessary works. This includes selection of the appropriate technique of measurement, suitable for the application at the site and definition of detailed numerical models enabling analysis of the considered structure at different levels of precision, e.g. general (global), selected structure segment, cross-section and local to account for environmental and operating conditions effects. The aforesaid analyses, depending on the required precision of gathered data, are related to linear and nonlinear problems of statics, stability and dynamics. Material, and geometric nonlinearities are considered. The material nonlinearities accounts for rheological effects, plasticity and crack development. Such an approach enables detailed behaviour description of the most sensitive regions of the buildings regarding the diagnostics aspects, or important construction stages as for example prestressing or regulation of tendons/membrane suspension systems.

A total number of 13 papers are shown here in order to present the scientific aim of research, results of analyses and their practical application. These were selected from 65 articles published after the PhD defence. They are, in the Author opinion, some representative examples of research and technological problem solutions. The chosen papers are divided into 3 groups, depending on the type of the analysed building. The first one concerns bridges, the second one includes roofs and tendon-membrane flexible systems, while geotechnic or hydraulic structures are considered within the third group. The paper [Z4.I.B.13] is a sort of summary of the scientific goal achieved in my research. It describes the possibility of risk reduction in design processes and during construction works, as a consequence of appropriate diagnostic tests and structural health monitoring data analysis before the structure is accepted to carry traffic~~ or structural health monitoring data analysis~~.

Bridges

Grot-Rowecki's Bridge over the Visitula river in Warsaw, S8 express road

Evaluation of the response of longitudinal ribs of the deck and structural members in the area of supports of the Grot-Rowecki's Bridge in Warsaw was the problem to consider. It was selected from among 302 diagnostics tests, the so-called final acceptance tests aiming to load the structure up to its ultimate limits before it is accepted to carry traffic, which were supervised and led by the Author. The bridge is constructed as two, the same superstructures and underwent modernisation in the years 2013-2015. The theoretical lengths of each superstructure spans are L_t = 75 + 3×90 + 2×120 + 60 *m*. The modernisation included:

- extension of the road width, enabling increase of the number of road lanes from 8 to 10 (the total width of the road changed from 18,5 + 18,5 to 23,1 + 23,9 [m]) and construction of sidewalks (2×2,5 *m*)
- construction of new load bearing elements in order to increase the allowable loads to be carried by the bridge (according to the code PN-85/S-10030 the superstructure and substructure should sustain loads of class B, while the deck should carry load class A + Stanag 150)

In order to meet the requirements dictated by the higher load class Designer decided to: externally prestress the existing structure; replace (cut off) the existing cantilevers with wider ones braced by struts (Fig. 4.1).

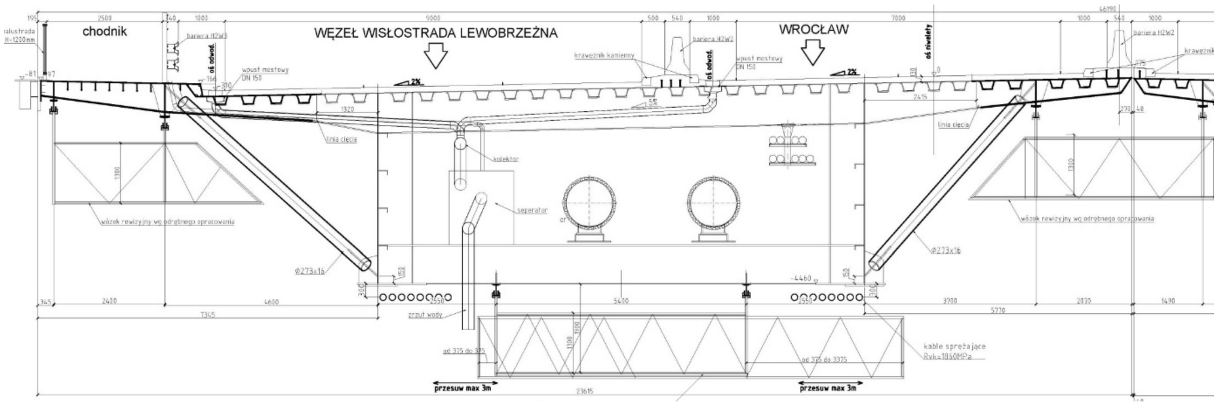


Fig. 4.1. Cross section of the Grot- Rowecki's bridge in Warsaw after modernisation works

The program of bridge testing was based on in-situ measurements and numerical calculations of the whole superstructure (global model) and bridge segments (local models), including nonlinearities [Z4.I.B.1]. The problem to assign appropriate conditions on the boundaries of local models (Fig. 4.2), which enforce behaviour of local model in accordance with the global response of the superstructure was the issue that required original Author's approach.

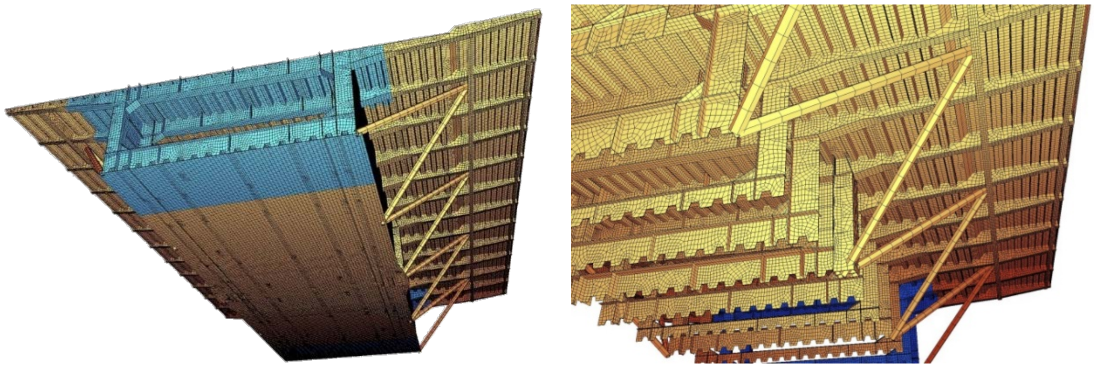
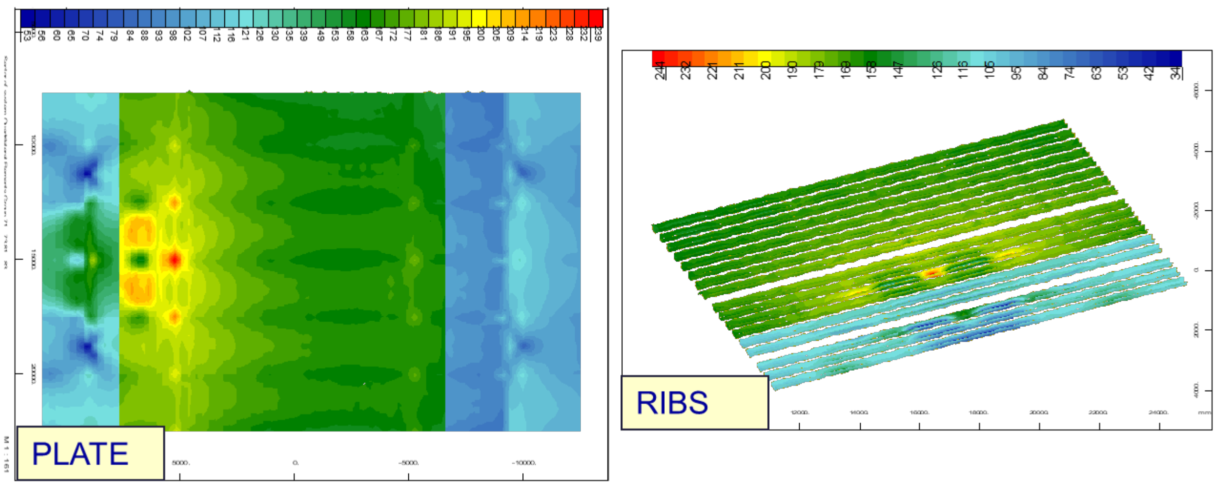


Fig. 4.2. Visualisation of a selected local model of the Grot- Rowecki's bridge in Warsaw

A series of numerical tests were conducted in order to verify whether the assumption underlying creation of the local models of bridge sections are valid. Different loading conditions were analysed in the course of the tests, also states of virtual loading were considered. The tests aimed to confirm the compatibility between the measurable variables from the global model of bridge superstructure and the local models of bridge sections in matters of section forces and stress. These variables were checked in control points located within the steel deck and the lower flange of the box cross section along the bridge axis. The numerical models were very detailed and therefore suitable for analysis of local phenomena. These had to fulfil the aforesaid conditions of compatibility with the global description of bridge behaviour and also the global equations of equilibrium resulting from the mechanical conservation laws. The obtained results indicated that a favourable redistribution of stress occurred in the bridge deck. In consequence the equivalent stress, according to the Huber-Mises-Hencky (HMH) hypothesis, decreased, compared to the ones estimated in the global analysis. The algorithm chosen for the purpose of this research enabled a more precise description of the state of stress in the deck and thus a more detailed representation of behaviour of longitudinal ribs (Fig. 4.3). What is more, the dynamic response simulations under a vehicle passing the bridge confirmed that there is only a very low influence of dynamic excitations on the local response of the structure. From this reason a crucial decision was made to resign from the additional modifications and stiffening of the longitudinal ribs. All the numerical estimation were carried out on meshes of finite elements that meet the formal requirements of the convergence of FEM results.



Rys. 4.3. HMH stress distribution contours in the deck and in the longitudinal ribs obtained in the local analysis of the Grot- Rowecki's bridge in Warsaw

The appropriateness of the FEM numerical simulations was evaluated by comparison with measured in-situ values gathered by means of a system of vibrating wire strain gauges (VWSG) attached to the bridge (fig. 4.4). The use of a dozen of sensor of this type was truly appreciated by the General Contractor and Inspectors supervising the modernisation works, because of their quick and noninvasive application as opposed to the electrical resistance strain gauges. This system of sensors enabled a detailed analysis of the real behaviour of the superstructure.

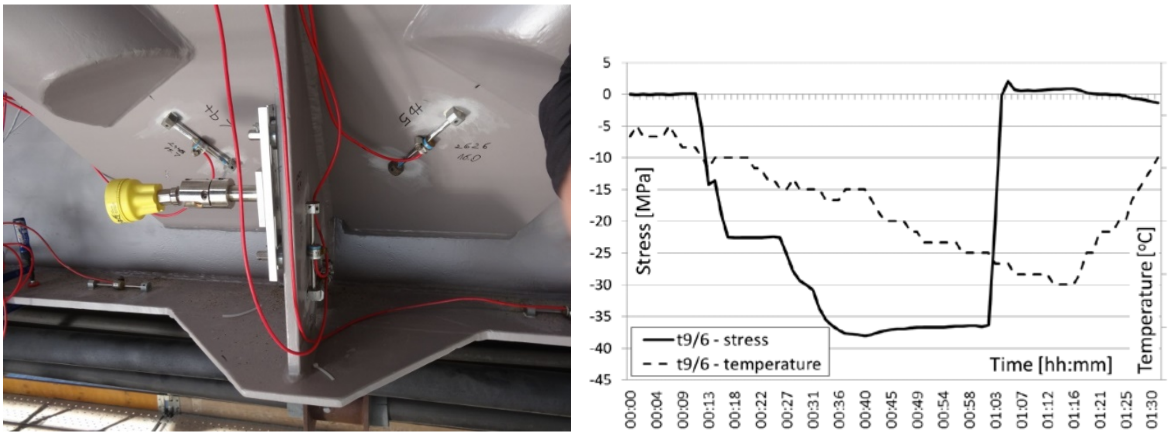


Fig. 4.4. Grot- Rowecki's Bridge in Warsaw; points of VWSG measure in the vicinity of truss struts connections (left), the change of stress and temperature in a longitudinal rib during diagnostics (right)

Algorithm and technology of the creation of bridge local models, that meet rigours requirements of compatibility with global model of superstructure and boundary conditions along with the procedure to verify the results using the system of VWSG measurements sensors, being relatively cheap and easy to install, are universal achievements resulting from the diagnostics of this steel bridge.

Footbridge over the docks in Ustka

Another example of non-standard application of measurement techniques for the purpose of diagnostics (VWSG extensometers were used as well) is the analysis of the response of a swing-bridge over the docks in Ustka. The diagnostics took place as a part of an expertise and load testing before the bridge final acceptance. The bridge is an extraordinary suspended structure (theoretical span length is $L_t = 53{,}2\ m$). Its vertical axis of rotation runs directly through a rotating bearing of deck and a cantilever fixed to a non-movable pylon. The cables, which suspend the deck are attached to the cantilever (Fig. 4.5). The highest ratios of utilisation levels in the suspension system is observed when the bridge opens or closes, namely when it is during the swing phase.

Fig. 4.5. Swing-footbridge over the harbour in Ustka; during the load testing (left), numerical model visualisation (right)

The bridge was approved for the use under traffic after load testing in 2013 and was in service without any accidents for almost 2 years. Then, in the year 2015 an alarming behaviour was observed. The cables suspending the deck exhibited excessive vibrations, accompanied by acoustic effects. Some preliminary considerations indicated that the bridge foundations could have been moved as a result of construction works of fishing harbour and its access roads nearby the footbridge. From that moment a geodetic monitoring was launched. The data gathered from the load testing, force measurements in the cables and monitoring, was used to run numerous FEM calculations and to validate the model of the structure. Both, global results (displacements, accelerations), as well as local ones (strains, axial forces in cables) were used in the *Model Updating* procedure. The sensors attached to the bridge for the purpose of load testing and used in model validation, namely: 26 points of VWSG strain measure (22 on the deck, 4 attached to the cables), 25 points of accelerations registration and the measure of cable forces, allowed to describe the structure response in the model with high precision. Finally, the utilisation ratios of structural elements and modal properties were checked, for the conditions observed after the failure. The results indicated that the state of stress in structural members described with aid of HMH hypothesis is safe, despite that there are concerns about the dynamic response of the bridge (excessive vibrations). What is more, a redistribution of sections forces and changes in the axial forces of the suspension system were observed. The cause of the failure was identified basing on the aforementioned results, as internal resonance between certain cables and the whole structure for frequencies approximately equal 1 *Hz*. It is worth to mention that the incorrect accidental behaviour, that occurred in 2015 did not happen before. As a result of the analysis of geodetic diagnostic measurements, that pointed out that one of the pylon guy cable was pulled out from the ground, an inverse problem was formulated - what is the foundation total vertical upward displacement for the actual state of internal forces in the system. This problem was solved via parametric analysis with one control parameter (vertical displacement of the guy cable foundation) in order to prove that the axial forces change in cables is possible. The following parameters were treated as representative for the definition of the problem: normal force in the right guy stay, normal force in the longest cable suspending the deck and displacement of the pylon. The analysis results show that the value of displacement is close to 19 *mm*, whereas the displacement growth registered by geodetic measure was 6 *mm*. Nevertheless, the geodetic diagnostics started after the failure occurred, therefore, most likely the measured value is not the total value of vertical displacement of the foundation and the estimated one seems in view of that accurate, as the remaining control parameters are in good correspondence with the in situ values (Fig. 4.6). It needs to be emphasized that the critical foundation under consideration could have displaced in an uncontrolled way in the lateral direction as well. This results from a simple vector calculus and have an impact on the accumulated value and therefore on the final result.

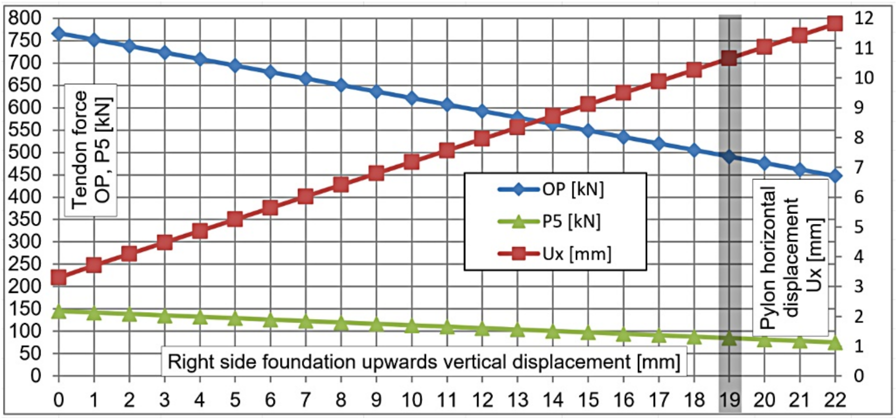


Fig. 4.6. Footbridge in Ustka. The change of control parameters in the solution of the inverse problem: left cable stay force (OP), normal force in the longest suspending cable on the bridge right side (P5), lateral pylon displacement (Ux), as a function of the vertical upwards foundation displacement

The numerical simulations present that the uncontrolled upward movement of stay cables foundations and excessive vibrations of the deck may have resulted in the change of axial forces in the suspending cables and were possibly triggered by construction of retaining walls by means of vibratory pile drivers at a distance less than a few meters from the bridge.

The algorithm created for the purpose of inverse problem solution, that used series of single parameter simulations, enabled theoretical evaluation of the impact of the vertical displacement of foundation on the response of the whole system.

FOBRIDGE composite footbridge

An important works, from the point of view of the application of diagnostic methods supported by FEM simulations, were conducted within the scientific grant acronymed as FOBRIDGE and cofinanced by the National Centre for Research and Development (NCRD). The aim of the grant was to design, build and test a composite footbridge (Fig. 4.7). This worldwide innovative footbridge is a shell sandwich structure (skins/laminates made of resin reinforced with glass fibres and core made of PET foam) having U-shape cross section. It is designed in such a way that the whole span is produced in a single production process of infusion technology, without any fasteners as connectors, barriers, glues, etc.

Fig. 4.7. FOBRIDGE project. The research bridge at the Politechnika Gdańska Campus

A series of numerical and experimental tests were planned to run during the project (Fig. 4.8). Properties identification of laminates (built of vinylester resin and glass fibres) and PET foam core was made. Behaviour validation of sandwich beams was performed, as well as behaviour validation and manufacturing tests (infusion) of a 3 m long bridge segment [Z4.I.B.4]. At the end of the grant the full scale bridge (span 14 *m* long) made for the research purpose only underwent the tests which are made during structure final inspection and acceptance [Z4.I.B.5, Z4.I.B.6]. What is more structural health monitoring was developed and created over the bridge [Z4.I.B.7]. All the results collected throughout the tests were used to validate numerical models built in FEM environment. The systems of measurement sensors were chosen at each subsequent stage of research to enable gathering of, as detailed as possible, mathematical information about the system (iterative validation).

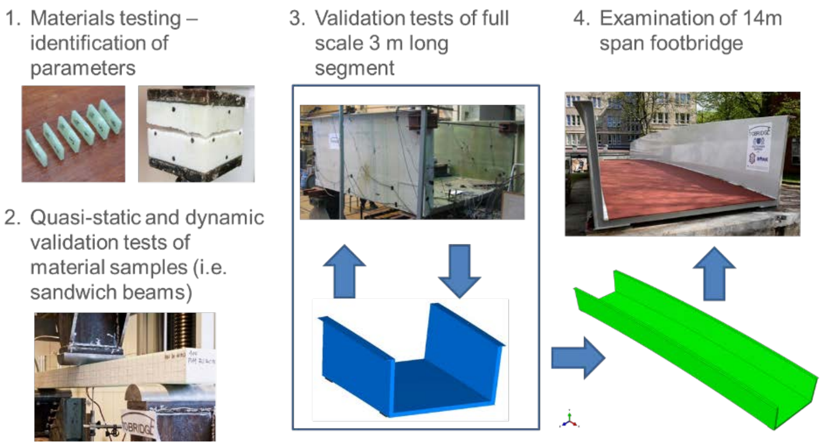


Fig. 4.8. FOBRIDGE project. Stages of research works, visualisations of FEM models

The measurements during the tests of the bridge segment (3 m long) [Z4.I.B.4] were made with aid of: 60 electrical resistance strain gauges, 17 inductive sensors, 32 accelerometers and 4 points where acoustic emission was registered. Figure 4.9 presents a comparison of the in-situ displacements and strains saved during the tests with FEM estimations from the validated model of the system. These were measured when the segment was subjected to a concentrated force of 50 *kN* via 200×200 *mm* square plate. This load is significantly greater than the crowd load $5kN/m^2$ or service car load (total weight 120 *kN*) which should be considered according to the current design codes when a footbridge is designed. Finally, after the testing of the bridge segment it was cut into smaller pieces and visually inspected. This aimed to find possible internal damages in the segment as delamination, regions where the resin did not infused the material, crushed foam.

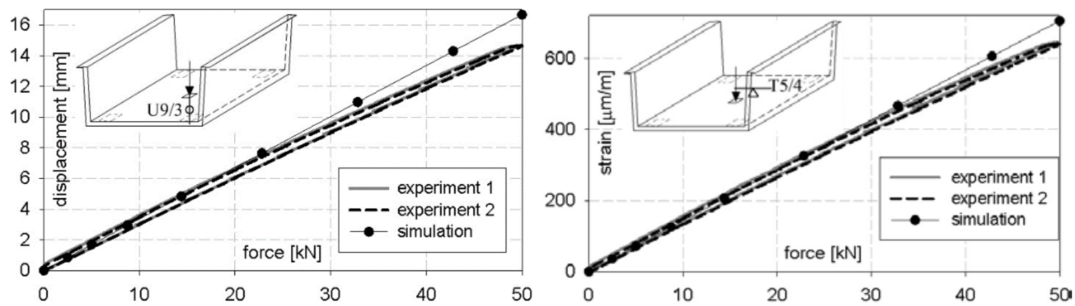


Fig. 4.9. FOBRIDGE project. Results registered during bridge segment tests compared to the numerical estimations

The results obtained during the bridge segment tests allowed to verify whether the manufacturing technology is appropriate to build a bridge with such a shape and to check if the measuring techniques can be used effectively in the considered footbridge. The evaluation of bridge segment behaviour allowed to validate the FEM numerical models (pure shell ESL, only 3D solid, shell – solid modelling) and their use during the design of the full scale bridge (Fig 4.10), which was subjected to a variety of short [Z4.I.B.5, Z4.I.B.6] and long-term testing [Z4.I.B.7].

Fig. 4.10. FOBRIDGE project. The footbridge during the static load test. Concrete slabs having a mass of 20 *t* are put on the bridge - this load corresponds to 120% of the design live load according to the current codes (left), a view on some of the measuring points (right)

However, other measuring techniques, used hardly never or rarely in civil engineering in Poland were also adopted apart from the regular ones (strain gauge, inductive sensors, precision levelling, total station surveying). Due to the internal structure of the utilised material FBG sensors were immersed into the load bearing skin layers, which enabled the measure of strains. Terrestrial Laser Scanning was performed to create a 3D image of the footbridge deformations [Z4.II.A.3]. What is more VWSG were used to perform long-term strain monitoring. All the aforementioned techniques allowed to gather new knowledge about the response of a footbridge having the form of sandwich composite shell. The results of the short-term testing (Fig 4.11), which were repeated 3 times in different seasons for the same loading conditions, confirmed that the response of the footbridge was elastic for the whole time and the global stiffness properties of the structure did not change as well, except small changes in the material properties due to the diurnal and seasonal changes of temperature. The comparisons of the FEM analyses and in situ values for the girder revealed that the real response of the system was a dozen or so percent better than the one estimated by means of calculations. This is attributed to the fact that, by an assumption the numerical models did not include stiffness coming from additional technological layers giving protection to UV radiation, abrasion, impacts or due to some amount of resin infused by the foam at the skin-core contact surface.

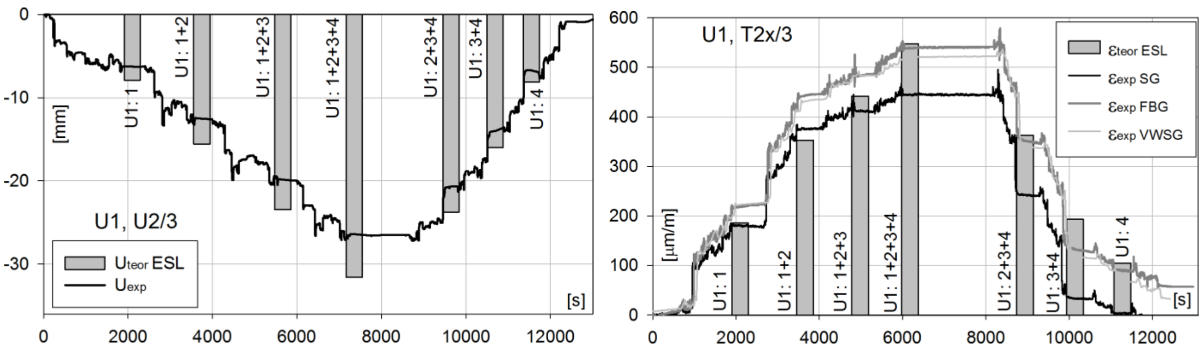


Fig. 4.11. FOBRIDGE project. Results of the static load tests and the comparison with the FEM estimations: displacement in the middle of the deck at the mid-span (left), longitudinal strains at the mid-span under the wall of the U-section (right)

A modern structural health monitoring was mounted on the full scale object. It was based on a six-channels prototype sensors to register vibrations. The sensors comprise of three integrated with each other orthogonal channels to measure directional accelerations and three orthogonal channels to measure rotational speed. For the purpose of continuous SHM, when the footbridge was tested at the University Campus, the following devices were used:

- 15 points of strain measure: 3 FBGs, being a permanent equipment of the bridge through its life cycle and 12 VWSG which can be demounted
- 18 accelerometers,
- 18 sensors of rotational speed measure,
- 16 temperature change sensors.

The parameters registered constantly by the aforementioned devices were additional checked at specific, periodic intervals by geodetic total station surveying in 14 points located over the bridge. The SHM did not reveal occurrence of creep effects of the laminated skins made of resin and glass fibres (fibre weight fraction ~60%) under permanent loads and static load tests repeated three times. The change of displacements (Fig. 4.12) correlated with the environmental conditions. As it was stated earlier these changes have a small impact on the elastic properties of the laminate layers.

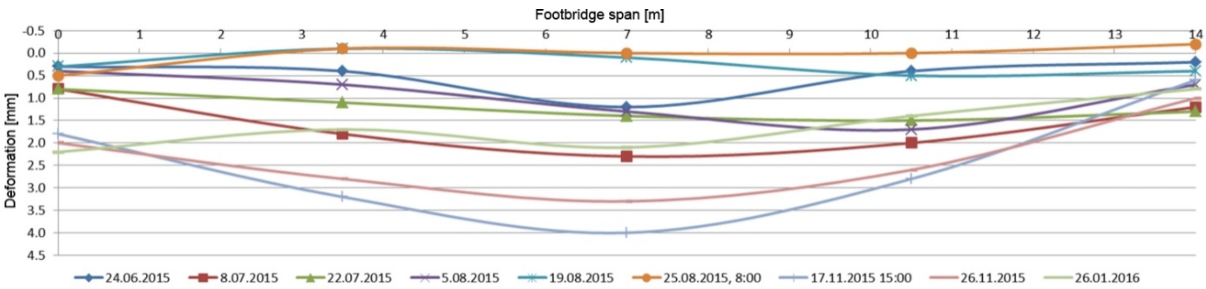


Fig. 4.12. FOBRIDGE project. Results of periodic measure of displacements along the footbridge span under its self-weight only.

The long-term creep effect tests were additionally extended to 12 weeks. During this time a ballast of 14 *t* (89% of the footbridge design load) remained on the bridge deck. This test did not reveal any negative rheological influences of the co-designed by the Author sandwich composite bridge. This is shown for example in Fig 4.13. When the bridge was unloaded it returned to its initial geometry in an elastic way. It is worth to mention that the results of local measurement of strains and temperature confirmed that the diurnal and seasonal changes of temperature influence the state of strain in laminated skins of the bridge.

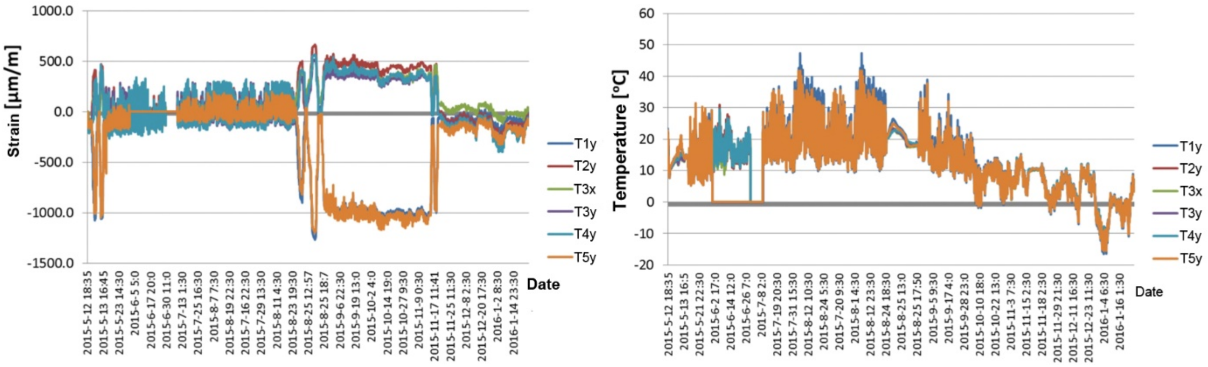


Fig. 4.13. FOBRIDGE project. Strain (left) and temperature (right) measured at the mid-span, registered during long-term testing from 15th May 2015 to 14th January 2016. The change in strains reveals the effects of short and long-term loads applied to the bridge as well as the diurnal and seasonal changes in temperature.

The applied methods of measurement allowed to collect at each stage of the project useful and important information enabling precise validation of FEM models of the structure. As an effect of the project some universal algorithms and findings were devised. These can be employed in the analysis and design of lightweight composite sandwich footbridges. This efforts have been already appreciated by the international science. The built span, because of its fast production, being a few days only at industrial scale, maintenance works which are in fact required hardly never, competitive price calculated for the whole life cycle of the bridge, compared to the one calculated for a steel, concrete or wooden bridge having similar dimensions, is unique and innovative on a global scale. This research project, after it ended, got high rating from the cofinancing institution (NCRD). What is more the footbridge, initially built only for research purposes, was mounted over the Radunia River in Pruszcz Gdański and accepted for pedestrian/cyclist traffic. Now it is a part of a cyclist road and is used in real conditions. The bridge manufacturing process got a patent protection in 2018.

Soil –steel bridge made of corrugated sheets

Interdisciplinary and comprehensive diagnostic tests of final bridge inspection and acceptance have been proposed for a soil – steel viaduct made of corrugated sheets, being the European span length record holder (25,74 *m*). As an effect of an original Author's concept a detailed and precise information about the structure response was collected [Z4.I.B.8].

The numerical simulations of the bridge behaviour were performed by means of FEM. Nonlinear static and linear dynamic calculations were executed. First order solid elements with linear shape functions and additional formulations that prevent occurrence of the locking effect when full integration is incorporated were used to describe the soil continuum. Whereas linear, C^0 class shell elements with some formulations making them almost free of the locking phenomenon were utilised to model the steel sheets. In the central part of the structure, namely in the region where the in-situ measurements were taken, the corrugated sheets were modelled in details having regard to the real geometry including corrugation. A simplification was made outside this region (close to the bridge ends), where the steel sheets were treated as a shell endowed with equivalent orthotropic properties and thickness (Fig. 4.14)

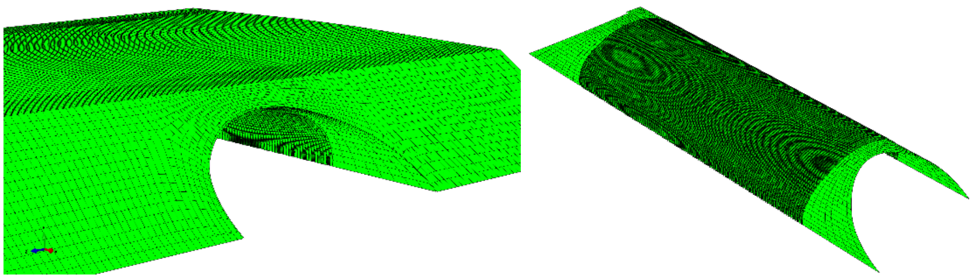


Fig. 4.14. Shell – soil viaduct. FEM models visualisations

The in-situ measurements were done with aid of: inductive sensors, optical total station, terrestrial laser scanner. Experimental modal analysis was also carried out. The results produced by terrestrial laser scanning were used to build a precise image of structure deformation in 3D space during the tests. For that purpose a 2×2 *mm* grid of measurement points was established over the bridge (Fig. 4.15). The precision of laser mapping was additionally significantly increased by means of image tracing (vectorization) and calibration of results through parallel verification of the collected data with the values coming from optic total station (14 points of measure) and inductive sensors (8 points of measure). The Author's measurements algorithm enabled to improve the accuracy of the in-situ terrestrial laser scanning from the absolute nominal ~2 *mm*/10 *m* to 0,3 *mm* regarding lateral axes *X* and *Y* and 0,01 *mm* regarding vertical *Z* axis.

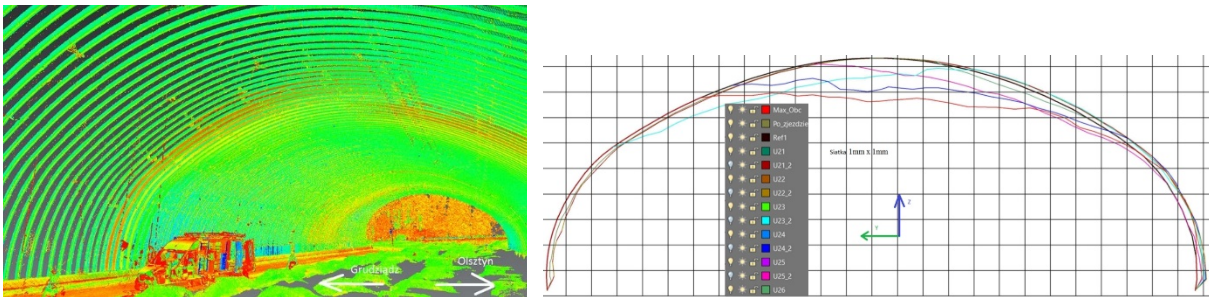


Fig. 4.15. Soil – steel viaduct. Cloud of points collected during the tests (left) and the change of displacements in one of the measuring sections for 6 different position of static loads during the final acceptance tests (right)

The aforementioned procedures and algorithms aiming to increase terrestrial laser scanning accuracy are the Author's achievement and are being an important step forward in the field of application of the laser scanner for the purpose of structures diagnostics. The full 3D deformation image of the steel shell, having the following dimension in the plan view 100×26 [*m*], with the achieved precision (*X*, Y ~0,3 *mm*; Z ~0,01 *mm*; for the 2×2 [*mm*] grid of measurement points), can be considered as unique scientific achievement. The image satisfies the conditions of the reference state in the case of structure monitoring, and possible periodic diagnostics in its life cycle.

Roofs

The Forrest Opera in Sopot

Laser scanner was also successfully used during the diagnostics of the roof of the Forrest Opera in Sopot [Z4.I.B.9]. However, in this case, because of relatively big displacements (locally approximately a dozen centimetres), no additional techniques of measurement accuracy increase were required. A different problem was analysed here, aiming to determine the real state of the membrane tension and also to eliminate the regions where the membrane was folding.

The analysis of this strongly nonlinear situation required formulation of the inverse problem. The plan of the research included static load tests of the roof and measurements of the roof membrane spatial deformations by means of the laser scanner (Fig. 4.16).

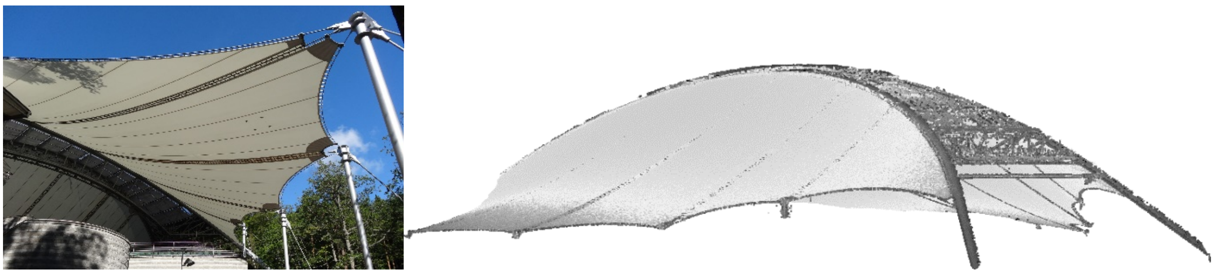


Fig. 4.16. The roof of the Forrest Opera in Sopot. The membrane (left), cloud of points registered during the tests and being the mathematical image of the membrane (right)

The collected information was then used as input data for the solution of the inverse problem with aid of FEM environment. The geometry of finite element mesh was created according to the membrane measurements (Fig 4.17).

Material properties of the membrane were identified as well as the information about the test ballast and used in the calculations. Finally, the Author devised an algorithm in FEM environment, which determined the state of tension in the warp and weft directions in such a way that the calculated deformations corresponded with the in-situ identified one. (Fig. 4.18).

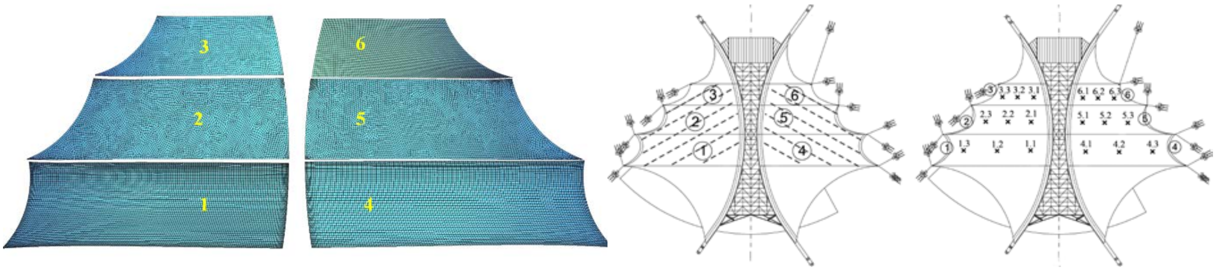


Fig. 4.17. The roof of the Forrest Opera in Sopot. Mesh divisions (left), numeration of the analysed panels in the plan view (middle),
locations and schemes of the static load tests used during the testing (right)

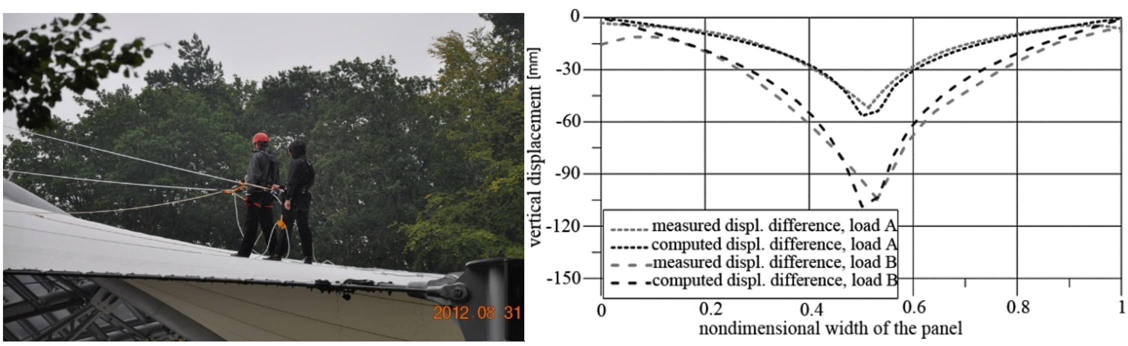


Fig. 4.18. The roof of the Forrest Opera in Sopot. Workers standing on the roof, acting as a concentrated loading ballast (left), measured and calculated deformation of the membrane in the panel 4 as a consequence of the loading (right)

The results of the inverse problem solution confirmed that the membrane tension was in accordance with the design project in both warp and weft directions. This was additionally and independently verified by the membrane Manufacturer in the selected regions of the roof with aid of MSM II BLUM device, which is suitable to measure local tensile stress of the membrane. It is emphasized that the roof diagnostics approach proposed by the Author is more universal than the one made by the Manufacturer, as it enables the description of the state of tension in the whole roof instead of giving an information in the selected regions of the structure. What is more, in order to perform nonlinear analysis of the membrane an Author's non-commercial FEM code was implemented. The solution of nonlinear behaviour was done with aid of Newton-Raphson iterative algorithm. This compact code, as opposed to the commercial systems, was able to automatically calculate numerous variants of tension states in the membrane in order to find the one matching the in-situ scanned deformation.

Olivia Sports Arena w Gdańsku

In the diagnostics of the Forrest Opera in Sopot the experiences gained during the design, creation and operation of the SHM system of the Olivia Sports Arena roof in Gdańsk were utilised [Z4.I.B.10]. It was proposed for the diagnostics of the Olivia Sports Arena to make use of results of the static load tests of the roof for the purpose of validation of nonlinear FEM calculation module implemented by the Author. The module was one of many other components of the roof SHM (Fig 4.19). It was assigned to constantly execute nonlinear numerical simulations basing on the data from the measurement points. The safety of the roof in each important location was then assessed on this basis.

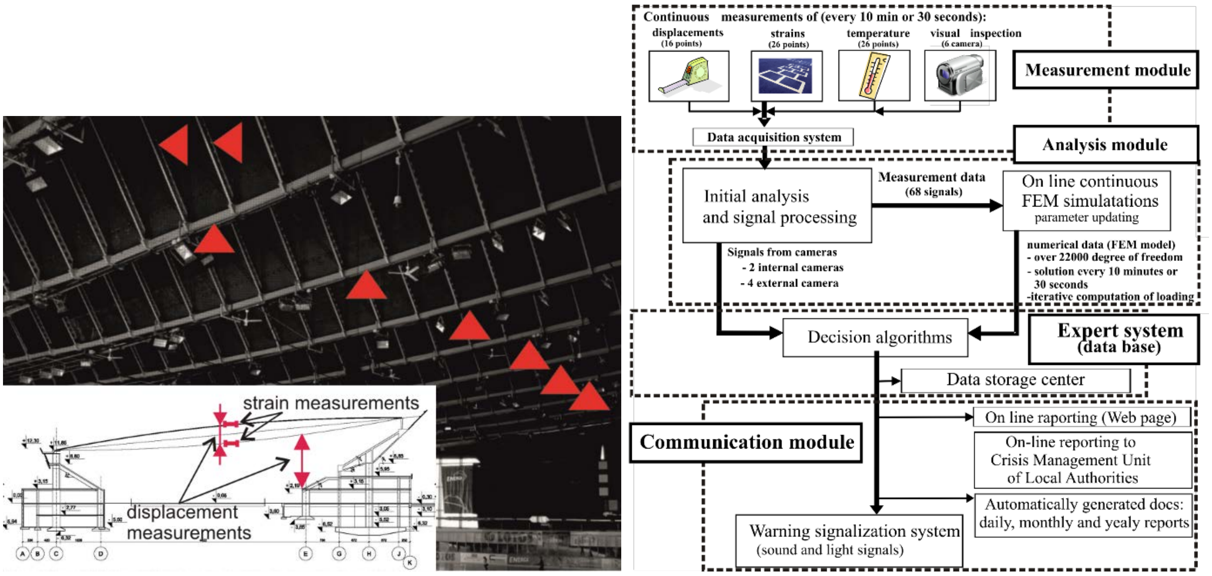


Fig. 4.19. Hala Olivia Roof in Gdańsk. Location of measurement points (left), the SHM process flow diagram

The in-situ testing of the roof was done for static loads and dynamic excitations. This allowed to determine the reference state of the structure deformation and the results of testing were used to validate FEM numerical models. The crucial issue in the simulations was related to the definition of appropriate boundary conditions of the spatial roof structure. Finally, procedures were established and software was programmed to allow analysis of different scenarios of the roof behaviour, including its failure. The paper [Z4.I.B.10] presents definitions of some indices describing the response state of the roof, important from the point of view of SHM. The diagnostic procedures implemented in the aforementioned Author’s module enabled to determine the state of the structure as: NORMAL, WARNING, FAILURE basing on the J index, defined as $J = a_1 \cdot I_1 + a_2 \cdot I_2 + a_3 \cdot I_3$, where I_1 represents the difference between measured and calculated values describing the state of the structure, I_2 describes the change of parameters values (geometry, buckling forces, forces in tensioning cables), whereas I_3, is responsible for the determination of the rate of parameters change. The I_1, I_2, I_3 indices are some normalized values. The a_1, a_2, a_3 are some weight coefficients that determine the importance of the I_1, I_2, I_3 indices according to the actual behaviour and deformation of the structure.

The knowledge data and experience gathered during the monitoring of the Olivia Sports Arena roof in Gdańsk were used to propose universal plan of SHM operation (Fig 4.20), which is based on two parallel processes – diagnostics of the structure response and decision making about required maintenance works, for example removal of snow from the roof.

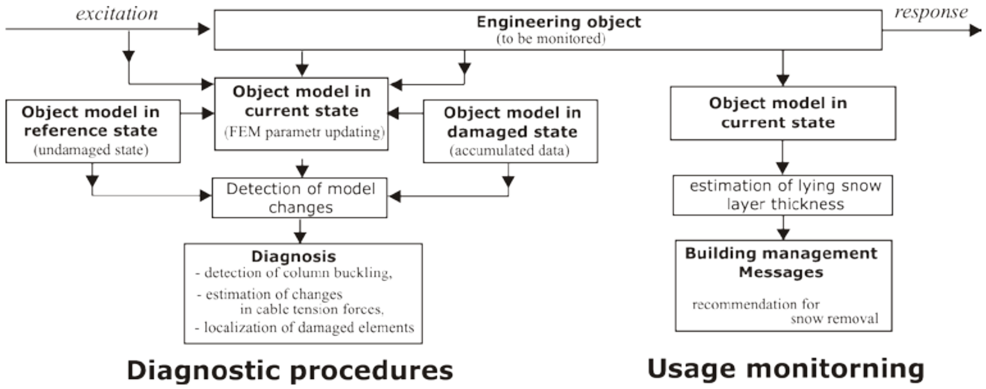


Fig. 4.20. Olivia Sports Arena roof in Gdańsk. The universal plan of SHM operation.

Geotechnics/Hydraulic engineering

A significant part of my scientific achievements and research, after receiving PhD title, is related to application of SHM of 20 structures. Primarily, the geotechnical [Z4.I.B.11] and hydraulic structures [Z4.I.B.12] required non-standard scientific or technological approach and at the same time provided unique data and have not been published by other research centres (according to the Authors' knowledge)

Road embankment along the Stawiski city bypass

The first paper [Z4.I.B.11] describes the SHM of an innovative road embankment near the bridge along the Stawiski city bypass (road number DK61) (Fig. 4.21). The embankment was founded on concrete *Controlled Stiffness Columns (CSC)* via load transfer platform reinforced with grids of steel bars. The tests which were made here, because of lack of design guidelines for structures of this type, aimed to deliver as much information as possible about interaction between load transfer platform and concrete columns and settlements during construction stages and during regular operation of the embankment. The collected data is unique for Designers of similar structures, as it enables validation of FEM numerical models. (Fig 4.22). Even nonlinear computations of the embankment response can be seriously uncertain, due to the complexity of the structure behaviour (interaction of columns, soil and transfer platform), when they are not validated or verified by some reference results.

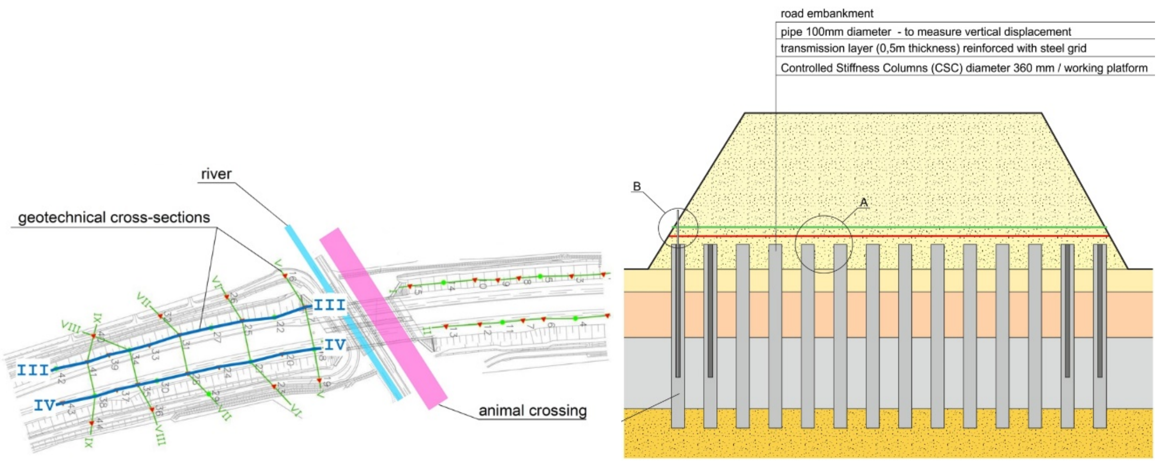


Fig. 4.21. The road embankment. SHM plan view (left), embankment cross section (right).

Due to restrictions of the number of possible measurements to perform, which was important aspect of the diagnostics programme, the type and number of measurement devices were chosen with care. Finally a decision was made to use: strain (force) sensors in external columns in 12 locations, soil pressure distribution sensors in 4 points of measure, pile heads pressure distribution sensors in 2 points, 16 strain (force) gauges in the reinforcement grid, inclinometer sensors in the external CSC columns and in the soil layers between columns and settlement sensors. (Fig. 4.21 right, Fig. 4.22 left).

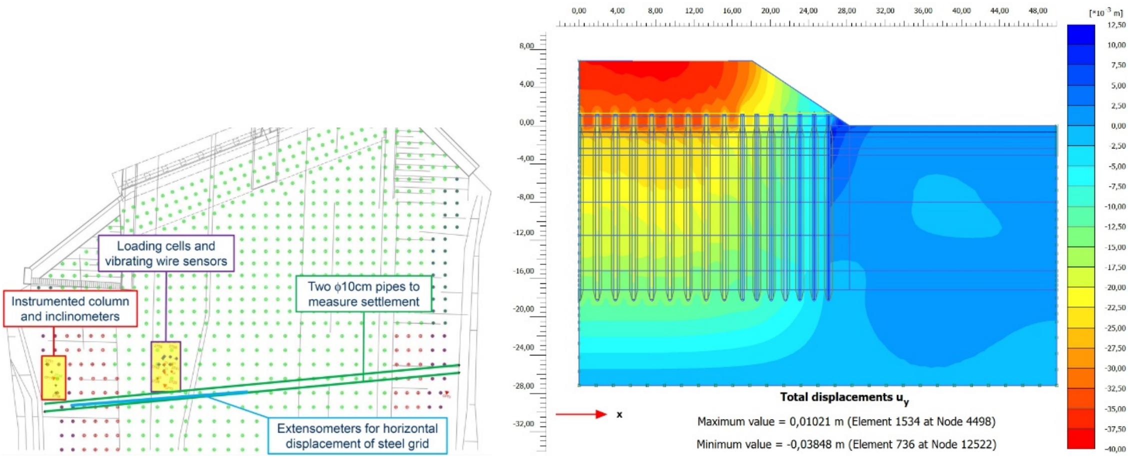


Fig. 4.22. The road embankment. Location of measurement points (left), embankment settlements under self-weight, according to the design project, results of FEM analysis (right)

Most of the measurements were taken with aid of VWSG sensors, short gauge length extensometers, each individually protected against damages and tested in laboratory (Fig. 4.23 left) and pressure distribution sensors (Fig. 4.23 middle). Long gauge length extensometers and sensors enabling settlements measurements in the whole embankment cross section were designed specifically for the purpose of this research. In order to measure the settlements PCV pipes were installed in the embankment. The pipes were in later stages of tests used to put liquid levelling system into them (Fig 4.23 right). The liquid levelling system enabled to get a unprecedented precision of settlements measure, ie. ~1 *mm*.

Fig. 4.23. The road embankment. Sensors of the reinforcing grids (left), Pressure distribution measurement points (middle), PCV pipes, where the liquid levelling system was installed (right)

All the tests of the embankment behaviour enabled verification of the design assumptions. The maximal values of embankment settlements, measured on site equalled 150 *mm*, whereas the numerical simulations estimations suggested that this values should have been close to 100 *mm*. What is more the tests revealed that the settlements along the considered cross section tend to be asymmetric (Fig. 4.24).

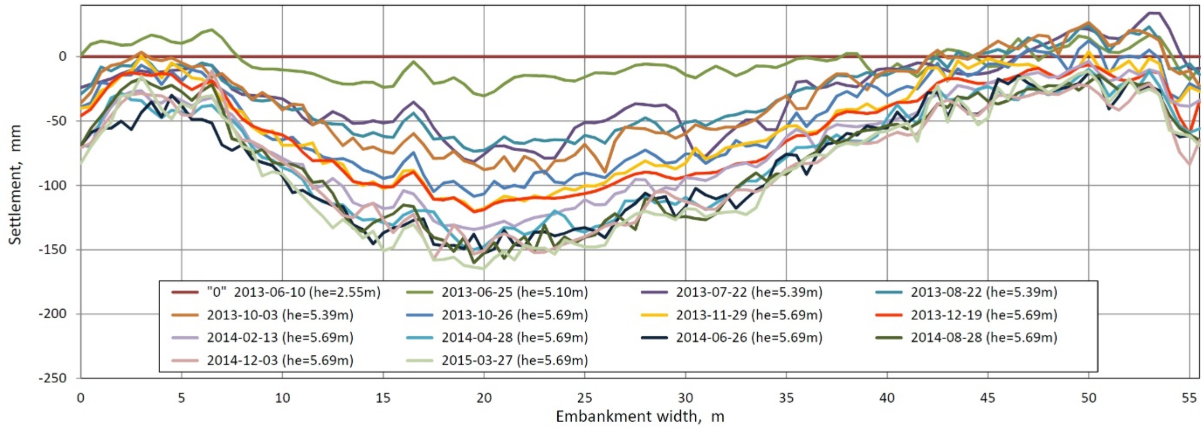


Fig. 4.24. The road embankment. Settlements at the bottom of embankment along the considered cross section in the embankment operation phase from 2014-06-26.

The road embankment Designers had a possibility to access the measurement results at each stage of the embankment construction and during its operation. This considerably limited the risk of failure during the construction of this innovative structure. What is more the collected data allowed to modify the design approach of another structures of this type.

DCT container facility in Gdańsk (DCT Gdansk)

The limitation of risk associated with construction of the hydraulic structure - *Deepwater Container Terminal Gdansk* was the aim of the monitoring of axial forces arising in steel bars, from which micropiles anchoring rear (land-side) crane girder were made of. [Z4.I.B.12]. The sea-side girder was designed as pile capping beam. It is supported by a combined wall made of pipes and steel profiles and is anchored to the land-side girder by means of pair of tie-rods. The land-side girder is founded on battered CFA piles and additionally anchored by the aforesaid micropiles which are 31 ÷ 36 *m* long, depending on the soil properties (Fig. 4.25). The monitoring of the aforementioned forces was done in 7 out of 290 micropiles that were formed in the ground along the quay.

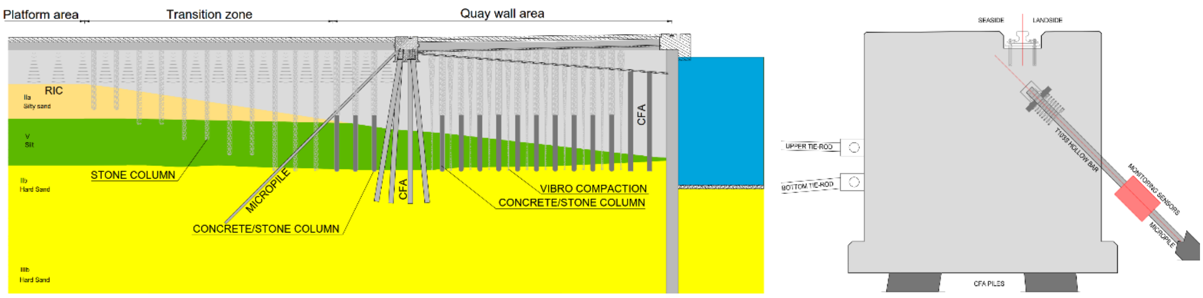


Fig. 4.25. DCT container facility in Gdańsk. Quay cross section (left), hinged connection of the micropiles and land-side crane girder beam (right)

Linear and nonlinear static FEM numerical simulations provided information about global and local response of the analysed structure. However, in order to verify the design project a decision was made to run load tests of micropiles and to install a SHM to monitor their behaviour. A regular SHM of such a structure consists of pressure distribution sensors, which are installed under the pile heads. This solution is however expensive. Therefore, an innovative system of axial forces monitoring, basing on strain measure in steel bars of micropiles was proposed. 7 measuring modules were built, 80 *cm* long each. All the modules were equipped with VWSG, which were calibrated in the laboratory using universal testing machine. The modules were protected against increased pressure in the water-soil environment by additional covers and shields. Each fully prepared for installation module was additionally checked in the laboratory to determine final calibration parameters (Fig. 4.26left). The modules were installed during scheduled construction site works (Fig. 4.26right).

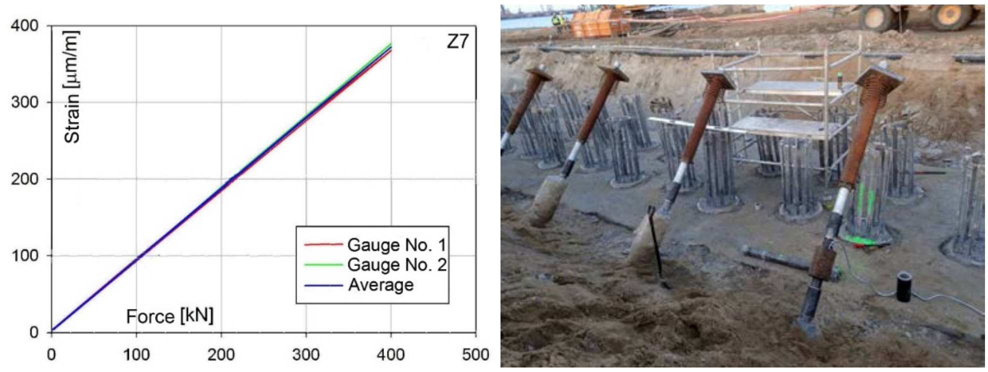


Fig. 4.26. DCT container facility in Gdańsk. Results of laboratory tests of the Z7 measurement module (left) the module mounted on the Z2 micropile bar (right)

The SHM allowed to monitor the forces in micropiles bars efficiently, while the analysis of design project and its assumptions at all stages of the behaviour of the quay and land-side beam allowed to determine the global behaviour character of micropiles. The highest force F_{meas}=724 *kN* was registered in the Z4 pile. The corresponding value of force at the same stage of behaviour, but calculated numerically is F_{calc}=807 *kN* (F_{meas}/F_{calc} = 90%). Hence, the monitoring system confirmed in a way that the design assumptions made during the design were correct. Nevertheless, the registered forces in all the analysed piles, as shown in Fig. 4.27, are not the same and big differences between them are observed. It can be stated that the distribution of forces in the bars along the quay is thus not uniform, whereas according to the theoretical considerations it should be uniform.

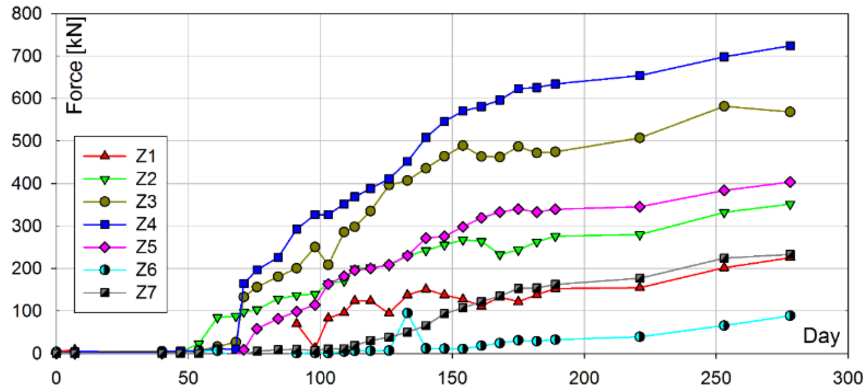


Fig. 4.27. DCT container facility in Gdańsk. The changes of forces in the micropiles rods during the diagnostics.

The paper [Z4.I.B.13] is a summary of the significance of the short and long-term diagnostics in the context of the limitation of risks in the design process and during construction works. Although its content is focused on the geotechnical structures (designed according to EC7) and the described case refers to the DCT2 container facility in Gdańsk, the aspects considered in the paper can be applied also to other problems and different structures. A conscious and rational way of the design of innovative structure with aid of novel diagnostics techniques also supported by FEM simulations has a lot of advantages shown in Fig. 4.28

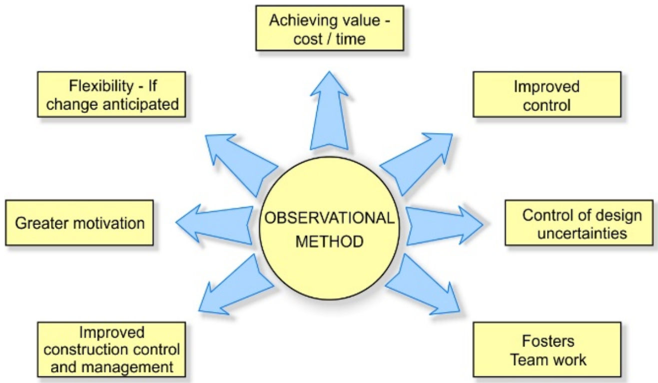


Fig. 4.28. The advantages of the observational method in the design process and during construction.

The tests made for the purpose of the design load testing and structural health monitoring of the quay allowed to validate FEM numerical models. The numerical analyses give an overview of all the parameters of the chosen structural solution at each stage of its construction and behaviour. What is more some of the data used to design the final shape of the structure was taken from the in-situ measurements. Fig. 4.29left presents the static load tests results. The axial stiffness ~160 MN/m was determined on the basis of these tests. Finally, after 500 days of SHM operation and 250 days from the opening of the DCT container the monitoring results confirmed all the conclusions described before.

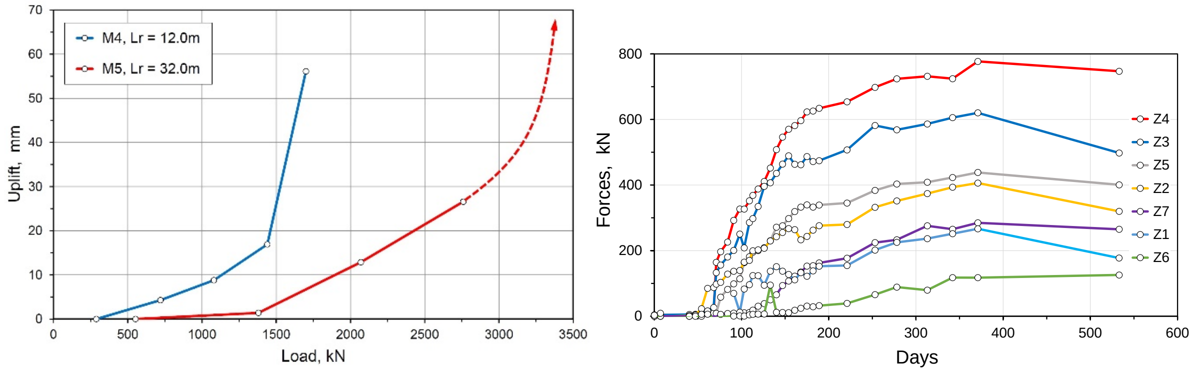


Fig. 4.29. DCT container facility in Gdańsk. Micropiles static load tests (left), Evolution of forces in the micropiles during the SHM operation (right)

Summary

The main achievement and contribution to the civil engineering discipline, presented in the papers, is development of methods of civil engineering structures diagnostics by means of in-situ measurements supported by advanced FEM numerical simulations. The series of publications, that constitute the scientific achievements, introduces a number of specific procedures formulated for the purpose of structure diagnostics and descriptions of the problems in the FEM environment. These can be used to solve advanced scientific and engineering tasks.

The developed algorithms, including mathematical models and numerical techniques, enabled to obtain the detailed overview of the parameters describing the technical condition of the structure. These included static and dynamic phenomena, local and global stability problems, in both linear and nonlinear range. The nonlinear problems of structures solved during my research works related to geometric and material non-linarites as well as rheological phenomena, plasticity or development of cracks in concrete. Research was focused on sensitive structure zones included in diagnostic procedures. The methodology of creating detailed local and global computational models was developed. The principles of mechanics and correct boundary conditions were assigned in a way that the full compatibility of models at local and global levels was ensured. This guaranteed the correctness of detailed simulation results. The proposed numerical procedures comprehensively described also the technical aspects of the construction works, e.g. construction stages and selected processes during the operation of the facilities. An important aspect of the conducted works was also the use of the latest measurement technologies such as, for example, laser scanning including the development of signal processing technology to increase measurement accuracy.

To sum up the presented achievements included in the scientific achievement concern the following research areas:

- application of innovative and interdisciplinary diagnostic tests of engineering structures, including bridge structures supported by advanced numerical simulations;
- inverse type problems in which the inference about the state of the structure is carried out by comprehensive numerical simulations based on a limited number of in situ measurement data;
- measurement and diagnostic technologies as well as continuous technical monitoring as tools for the safe and conscious design, execution and exploitation of engineering structures.

The participation and contribution of the author of the application in the publications indicated in the achievement are described in detail in Appendix 4.I.B. It is linked to supervision/coordination of work carried out by interdisciplinary teams of experts, participation in the execution of numerical calculations, considerations and analysis of the obtained results and paper editing processes. The management/coordination of research work has always involved the definition of strategies and the way of solving the research problem, the research program, the scope and methodology of the performed calculations as well as in situ or laboratory measurements. The developed applications required the preparation of new solutions that were the result of scientific and research work in the field of computational simulations and the application of measurement methods. The biggest challenge that I faced was the research done within the FOBRIDGE project (2013-2015). I was the project coordinator. My direct participation in experimental tests, mathematical modelling and numerical calculations, as well as the work related to the synchronization of the activities of external company working in the field of composites allowed me to gain competences that are important when applying for bold interdisciplinary research projects.

5. Summary of other scientific and research activities

5.1. Scientific activity

The scientific achievements after the doctorate are published in Annex 4, which included the following research areas:

1. designing a composite pedestrian bridge;
2. diagnostics of bridge objects (test loads, TLS and GPR scanning);
3. FEM simulations of bridges and other engineering structures;

4. technical monitoring systems.

The considered scientific and research issues created tasks related to the design, construction or maintenance of real structures. The research generated the need to solve a number of non-standard problems within the framework of tests commissioned by the socio-economic environment, final acceptance tests, implementation of monitoring systems, development of bridge assembly projects, applications and scientific supervision of erected structures. The application of newly developed research and computational procedures required in each case a broad insight into the analyzed issue. The most valuable achievement, in my opinion, is the participation in the research and design of the composite span of the pedestrian bridge.

Designing a composite pedestrian bridge

The composite pedestrian-bicycle bridge was created as part of the work carried out in the project with the acronym FOBRIDGE, co-financed by the National Centre for Research and Development. The project was carried out by a consortium composed of Gdańsk University of Technology (the leader), Military University of Technology, and ROMA Sp. z o. o. The aim of the project was to develop economically competitive, composite pedestrian-bicycle bridge spans intended for mass production. The supporting structure of the bridge is a freely supported U-type surface beam (Fig. 4.6), produced as a three-layer sandwich structure with laminate skins reinforced with fabrics made of glass fibre. The skins are separated by a thick core made of PET foam.

The design and manufacturing processes of the innovative composite bridge span, according to the assumptions and technology adopted in the project, required solving a number of issues due to the lack of specific standards, both in the area of national regulations and foreign literature. Standardized material data, guidelines for calculation and evaluation of material utilization ratios, standards for composite footbridges design and guidelines for large-scale infusion of thick sandwich elements were not available. To obtain information in this area it was necessary to perform a number of experimental, validation, and numerical analyses, as well as to conduct some technological tests related to the selection of material parameters and control of the infusion process.

The concept and the final detailed design of the U variant of the footbridge, including the experimental research necessary for the validation of computational models related to the design process; extensive static and dynamic numerical simulations of the linear and non-linear response using the finite element method; technical monitoring project, load tests project, and partial acceptance testing of the footbridge were performed by the team from the Department of Strength of Materials and Structures of the Faculty of Civil and Environmental Engineering of Gdańsk University of Technology. Computer simulations were conducted using own programs and commercial codes such as ABAQUS. As the main contractor, administrator, coordinator and co-designer of the span, I was directly involved in every stage of the work carried out in the project. My main achievement, presented in the academic achievement, is structural diagnostics supported by advanced FEM simulations. Nevertheless, I have also actively participated in other areas of analysis, research and design. Participation in the development of the span design was particularly important. However, it should be noted that, since industrial confidentiality needs to be maintained, the details of the project, with the exception of ones provided in patent 230477 [Z4.II.C.1], have not been disclosed in scientific publications.

Literature studies and review of the existing composite structures that have already been built in the world made it possible to develop cross-cutting publications [Z4.II.E.b.8, Z4.II.E.b.10] and guidelines that had indications for use in designing of the footbridge [Z4.II.E.e.9]. After the phase of analyzes and laboratory tests, results published in [Z4.II.E.e.12, II.E.e.14, II.E.e.15] and discussed during the conferences [Z4.II.L.a.27, Z4.II.L.a.28, Z4.II.L.a.29, Z4.II.L.b.25], the outcome of conceptual work was finally shown. This part was created in cooperation with a team of architects. It aimed at giving an impression of the bridge weightlessness, instead of exposing its unattractive massive parts (Fig. 5.1).

Fig. 5.1. Selected architectural concepts of a composite footbridge

After the phase of identification and validation tests at the semi-technical scale, testing of a 3*m* segment, being a full-size section of the bridge's span (Fig. 5.3), was started. The purpose of the segment creation was to choose appropriate production technology, as well as validate calculation models and test project assumptions. The quasi-static test programmes were launched to simulate possible loading conditions of the structure which were divided into 4 groups: A - vertical loading of the deck and handrails; B - inward bending of the handrail; C - handrail compression, D - combination of individual load schemes chosen from groups A and C. The obtained results were presented, among others, in [Z4.II.A.1, Z4.II.E.e.11, Z4.II.L.a.12]. The issue, the solution of which was crucial at this stage, resulted from the revision of the fact that the real structure was much stiffer compared to the FEM model made using the ESL technique. It turned out that an important aspect to consider, from the point of view of the structural response of the object, was the stiffness of internal transverse ribs that was higher than assumed theoretically in preliminary design.

The entire span created for the purpose of further research was located on the PG campus on temporary supports made from concrete road plates (Fig. 4.6 and Fig. 4.8). In static and dynamic tests, which were repeated three times in order to evaluate the change in structure characteristics over time, a total of 216 different types of measurement points were installed. During the static tests, laser scanning of one side of the span was carried out, and measurement points of the following were checked: deformations (strain gauges, extensometers and optical fibers sensors), displacements (inductive sensors, geodetic measurement), bearing deformations, and settlements of supports. The structure temperature was measured as well. During the dynamic tests, the following measurements were taken: deformations (strain gauges and optical fiber sensors), displacements (inductive sensors), accelerations and rotational speeds.

The aforementioned tests are presented in the works [Z4.II.E.a.5, Z4.II.E.d.1, Z4.II.E.e.7, Z4.II.E.e.10, Z4.II.L.a.9, Z4.II.L.a.10, Z4.II.L.a.20, Z4.II.L.b.22, Z4.II.L.b.24] - with a certain safety margin, they confirmed the correctness of the assumptions made at the design stage. Moreover, also an individually designed prototype bearing system, protecting against uplift forces of the light (about 3 tons) span due to wind, was proposed and approved during these tests.

The vibration forms, identified during the experimental modal analysis, corresponded with the theoretical values (Fig. 5.2). Dynamic characteristics of the innovative bridge span meet all the serviceability criteria, ensuring a high level of comfort [Z4.II.A.4, Z4.II.E.b.5, Z4.II.L.a.3].

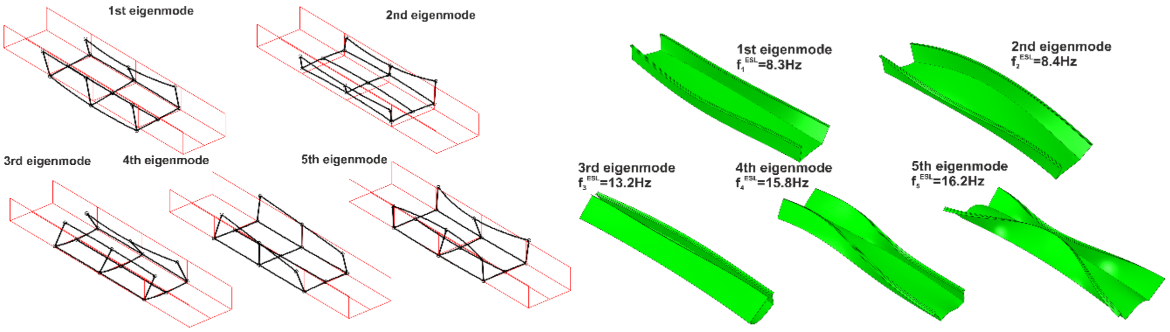


Fig. 5.2. Self-oscillation of the span: measured (left), calculated (right)

Eventually all the works conducted during the research project provided a significant amount of data on the behavior of composite bridges with a sandwich cross-section [Z4.II.A.5, Z4.II.L.b.9, Z4.II.L.b.10]. The "added value" of the grant, was consent of the National Centre for Research and Development to use the span, which was formally a research bridge only, as a truly pedestrian and bicycle bridge along the route crossing the Radunia canal in Pruszcz Gdański. Here, outside the scope of the grant, the research began within the framework of the project aimed at obtaining information about the span during its long-term operation (Fig. 5.3) [Z4.II.E.b.2, Z4.II.L.b.3, Z4.II.L.a.18].

a)  b)

Fig. 5.3. Composite pedestrian bridge over the Radunia canal in Pruszcz Gdański

Diagnostics of bridge objects

a) Test loads

Issues related to the construction diagnostics regarding research during the final acceptance tests of bridges are a significant achievement. These studies enabled the acquisition of experience both in the field of in-situ experiments and the area of theory, resulting from the FEM calculation models correlated with the tests. The acquired information concerned, among others, the cooperation of individual structural components and the influence of boundary and atmospheric conditions. In many cases, research problems related to the operation of interesting, complicated and often unique types of constructions were solved. The results and conclusions were presented in the publications [Z4.II.E.b.4, Z4.II.E.b.6, Z4.II.E.b.9, Z4.II.E.e.5, Z4.II.E.e.4, Z4.II.E.e.17] and during international [Z4.II.L.a.1, Z4.II.L.a.2, Z4.II.L.a.6, Z4.II.L.a.11, Z4.II.L.a.22] and national [Z4.II.L.b.4, Z4.II.L.b.7, Z4.II.L.b.8, III.L.b.15, Z4.II.L.b.23] scientific conferences. My participation in these studies after finishing my PhD was related to the management of the task, participation in the calculations, development of projects and reports and edition of the resulting publications. Due to the large number of works in the field (302 tests), I limit myself to presenting two of them clearly realizing not only technical goals, but also the scientific ones.

In the field of the description of in-situ tests and calculations correlated with them made during a load tests, the work [Z4.II.E.b.4] may be representative. The extradosed bridge with a single plane of external compression cables of a record span length in Europe (L_t= 132.5 +206 +206 +132.5 [m]) is considered there. This object was opened to traffic in 2017 and is located within the Ostróda bypass (DK63) (Fig. 5.4).

Fig. 5.4. Extradosed bridge on the Ostróda bypass (DK63). Setting of the trial load (left), visualisation of the FEM calculation model (right)

The scope of the static tests, besides the standard measurements for this type of object (displacements of the spans and settlements of the supports), included also deformation measurement of the entire structure, laser scanning, pylon displacement, and measurement of forces in representative external tensioning cables. In addition, an individual program of dynamic tests was developed, which of course included standard car passages in various configurations (Fig. 5.5). Nevertheless, the dynamic tests were primarily based on the experimental modal analysis.

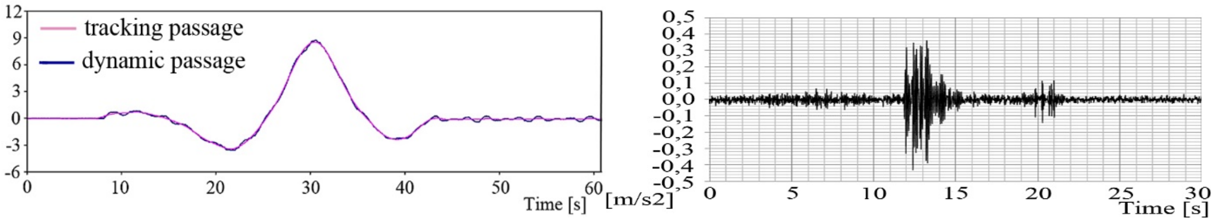


Fig. 5.5. Extradosed bridge on the Ostróda bypass (DK63). Change of displacements in the middle of the 206 m span while a car is passign the bridge at a speed of 70 km/h (left). Change of accelerations at the point in the middle of a 132.5 m span while driving a car through a threshold obstacle at a speed of 30 km/h (right)

The results registered during the tests were used to calibrate the bridge technical monitoring system, which will be continuously checking the behaviour of the structure until 2027.

Footbridge in Radom (Fig. 5.6) can be considered an unusual suspension footbridge (L_t= 40.2 m), in which a composite deck is suspended on a single main suspension cable. The footbridge was behaving perfectly under static in-situ load. However, in the case of dynamic excitations, some doubts were raised about the safety of the structure and possible risk of failure. This was also confirmed by FEM simulations. The possibility of structural failure of the original variant of the footbridge is associated with the form and value of the second natural frequency f_2= 2.54 h. The development of the research program included the implementation of experimental modal analysis and dynamic tests, to reflect effects vandalism acts [Z4.II.E.b.6].

Fig. 5.6. Footbridge in Radom. Side view of the structure (left), visualization of the FEM model (right)

It turned out that during a vandalistic test, i.e. when a 10-person group was jumping around the mid-span with a frequency close to the resonant, after the period of ~ 14 *s*, deck accelerations have reached the value of 4.51 m/s^2 (Fig. 5.7). The evolution of displacements and accelerations had a continuous upward trend, therefore the test was stopped, since it could have led to a structural failure.

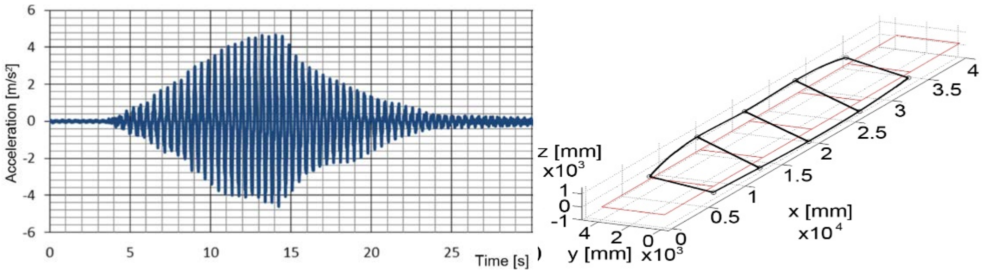


Fig. 5.7. Footbridge in Radom. Accelerations of the deck registered during synchronous jumps (left), the second form of natural vibrations identified on site f_2= 2.55 *h* (right)

The footbridge was not allowed to be used under traffic. It was recommended to install appropriate dampers and to re-commission the dynamic tests before starting exploitation. Computational verification of dampers installations confirmed their effectiveness [Z4.II.E.b.1]. Additionally, a technical monitoring system has been installed, adapted to control both static and dynamic behavior of footbridge [Z4.II.E.b.2].

b) TLS and GPR scanning

Currently, non-invasive measurement methods that include Terrestrial Laser Scanning and Ground Penetrating Radar enable identification of structure response [II.A.3]. As part of my scientific and research work, both measurement technologies were used. Since one of the areas of laser scanning applications has been described already in the achievement, here the results of the research problem reported in [II.E.a.1, II.E.e.2, Z4.II.L.b.18] are presented. Within this task, the combination of these two methods enabled non-invasive diagnosis of the causes of damage to the road surface in the immediate vicinity of the bridge. The damages were confirmed by in-situ excavations.

GPR scanning together with postprocessing were aimed at detecting possible discontinuities in the structure of the road surface SMA layers above the transition zone. The electrical conductivity scanning of individual layers was used, which during the in-situ tests revealed changes in the value of electrical permeability (Fig. 5.8 left). Changes in dielectric constant in the dilatation zone could indicate increased porosity or humidity of the tested medium.

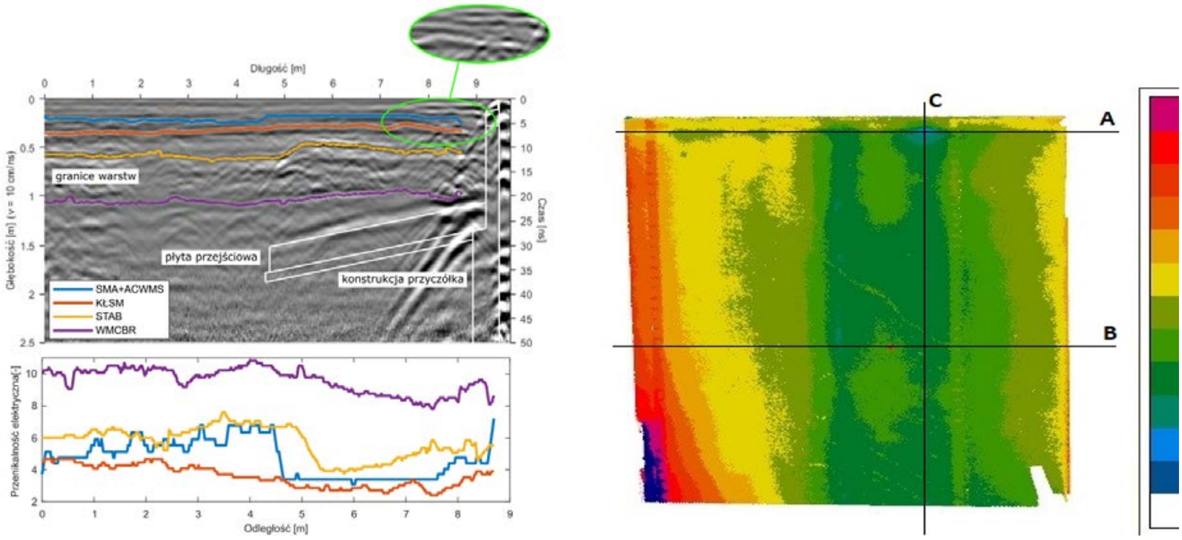


Fig. 5.8. Results of scanning road surface in the area of bridgeheads. GPR map with scanning of the busiest lane (left), isometric map of the scanned area (right)

Laser scanning of the area of dilatation of the bridge structures enabled the development of a spatial map of the isometric geometry of the road surface layers, showing deviations from the ideal geometry assumed in the design. Fig. 5.8 (right) clearly shows lowering of the right, busier lane by about 1 cm in relation to the reference surface. In the immediate vicinity of the dilatation, there is a surface positioned lower by 0.5 ÷ 1.5 cm in relation to the reference position on the right lane, and a few millimeters in relation to the left lane. Accuracy of measurement - after extraction of the point cloud, creation of the reference plane using method of least squares, alignment of the position with a modified ICP algorithm - is estimated to be ~3 mm.

Non-destructive tests performed during the analysis of the road surface were verified using standard approaches related to the collection and testing of core samples of the surface. Surface degrees of individual layers compactions were much smaller in the area of the abutments than a few meters away from it.

The utilised measurement techniques allowed to draw the conclusion about incorrect compaction of surface layers in the immediate vicinity of the dilatation. and, together with the documentation analysis, to identify the probable causes of its occurence.

FEM simulations

Various kinds of computational simulations presented in articles and during international and national conferences were an important issue discussed in relation to the analysis of the structures. These concerned in particular: problems of bridge dynamic response in the linear and nonlinear range [II.E.a.3, II.E.a.4, II.E.e.1, Z4.II.L.a.19, Z4.II.L.b.2, Z4.II.L.b.6, Z4.II.L.b.19], the influence of the bearing system on generation of internal forces [II.E.b.7, II.L.a.21], construction aerodynamics [II.E.b.3, Z4.II.L.b.17], analysis and optimization of the bridge's behaviour in its final state or in construction stages [II.E.d.3, II.E.e.3, II.E.e.6, II.E.e.8, II.E.e.13 II.E.e.16, Z4.II.L.a.13, Z4.II.L.a.14, Z4.II.L.a.17, Z4.II.L.a.26, Z4.II.L.b.1, Z4.II.L.b.11, Z4.II.L.b.12, Z4.II.L.b.13, Z4.II.L.b.14] as well as heating networks [Z4.II.L.b.20].

Due to significant number of achievements related to this topic, only works that are representative for the series of analyzes performed are presented. My participation in these works is shown in Appendix 4. The contribution to the solution of each of the presented problems was related to the management / coordination of the research team's work, co-deciding about the methodology for solving the issue, participation in the calculations and tests, and co-editing of the publication.

During the construction of tunnel / bridge constructions for the purposes of the Forum Gdańsk building, the task was to assess the impact of vibrations of the rolling stock on the structure and people staying in various facilities of the complex, e.g. parking lot, cinema, shopping mall, hotel [II.E.a.3, Z4.II.L.b.6]. The scope of work included identification of the structure in-situ response coming from dynamic excitations, from the trains passing the building, transferred to the already existing ground parts of the structure. Also numerical models in the finite element method environment (FEM) of the floor slab together with objects that were to be created there and their analysis under aforesaid dynamic loads was done.

Simulations and analyses of the dynamic response of the system (overall dimensions: *30-50 × 400 × variables*= X×Y×Z [*m*]), were conducted in a linear-elastic range. They took into account two states of construction work, i.e. without buildings and with structures intended for erection on the ground floor slab (Fig. 5.9). In terms of the correctness of FEM discretisation, the analysis of convergence of solutions was carried out. The influence of the density of the discretization grid, modeling of the boundary conditions with respect to the foundation method and the influence of individual sections connected with each other on their global and individual (local) dynamic response were examined.

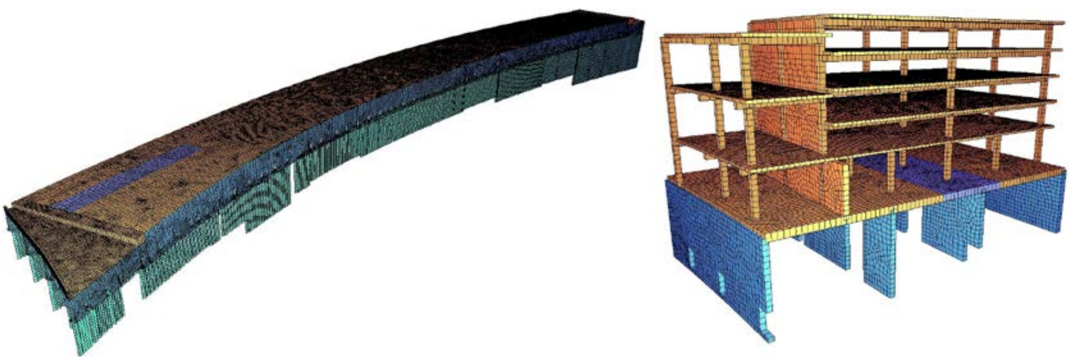


Fig. 5.9. Forum Gdańsk: Visualization of the numerical model of the structure without the above ground storeys (left), selected dilated section of the building with all storeys modelled(right)

The simulations were performed adequately to the conducted measurements. The ground vibrations in the mathematical model were excited by means of a signal obtained from direct in situ measurements in the three directions *X*. *Y* (Fig. 5.10) and *Z* during the rolling stock movement.

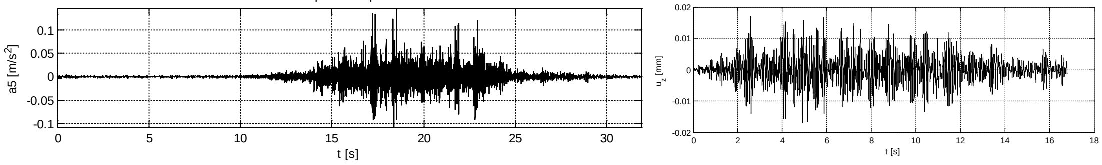


Fig. 5.10. Forum Gdańsk: a representative recorded vibration measurement as input data for FEM calculations (direction *Y* - horizontal, perpendicular to the wall (left), changes of displacements at the location of occurrence of extreme, representative values of accelerations of the floor slab section 2 (right)

To identify the impact of vibrations on the structure, the principle of superposition of small vibrations from rolling stock under the railway object, with finite static deformations from permanent interactions, was used. The analysis of changes in displacements of the kinematically enforced system, based on the measurement data of the object, indicated that the values φ of the dynamic factor fall within the range of 1.00042 ÷ 1.02429. The determined effective values of vertical accelerations, in the appropriate frequency bands, determined through the assessment of comfort of people staying at the facility in relation to vibration, indicated that the Forum Gdańsk space may be used for the purpose of relaxation, shopping, entertainment, etc. , as it was planned and designed, without any concerns.

Another type of problem are non-linear analyses of degradation of concrete (or reinforced concrete). The first of the examples mentioned in [Z4.II.E.a.4, Z4.II.L.b.19] is the analysis of the damage of the anchoring zone of the prestressing cables of the box-shaped bridge. During the construction works related to the implementation of the central longitudinal post-tensioning system, cracking of the concrete anchor blocks occurred. The subject of the research was to describe the mechanisms of the zone of internal cables anchors damage with the use of FEM environment. The purpose of the research was to determine the causes of cracking in the context of the designed and produced soft reinforcement system.

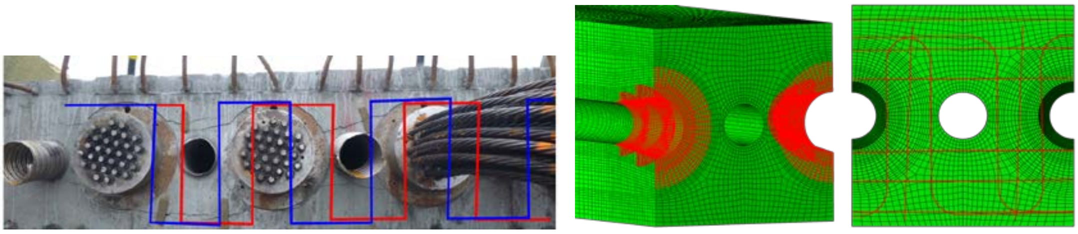


Fig. 5.11. Anchorage analysis: cracked on the active anchorage along with the applied reinforcement grid (left), the analyzed part of the structure with the mesh of solid finite elements and the soft reinforcement system (right)

Due to the local character of the phenomenon, the calculation model was limited to the description of the section of the top plate of the box deck with one unused cable duct and two adjacent active channels (Fig. 5.11). In addition to the description of the concrete body, the main reinforcement of the bridge and the local reinforcement of the anchorage zone and steel anchor heads were included as well.

Due to convergence problems of this strongly non-linear problem in terms of incremental static analysis, the problem was finally solved using a dynamic explicit approach. Numerical simulation of the post-tension process revealed that cracks are mainly propagating horizontally over the upper part of the anchor heads (Fig. 5.12).

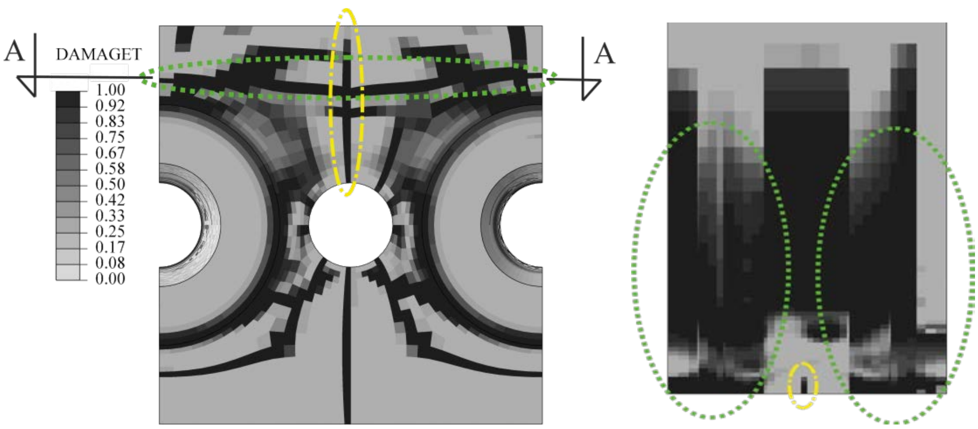


Fig. 5.12. The analysis of anchorage zone failure, distribution of *DAMAGET* parameter: on the front face (left), in the A-A section (right)

The conducted local analyzes indicated that the damages that occurred during the bridge construction are the result of the variant of used reinforcement of the anchorage zone and of too small volume of concrete in the area of the anchor block.

Analysis of dynamic explicit type, taking into account the non-linear nature of concrete behaviour was also used to calculate the response of a concrete double-span pre-tensioned girder (WD-113) along the S6 road on the Koszalin - Sianów bypass [Z4.II.E.e.1, Z4.II.L.a.19, Z4.II.L.b.2] (Fig. 5.13).

Fig. 5.13. Viaduct WD-113

The scientific issue addressed here regarded the inverse problem. The purpose of the simulation was to assess the possibility of pre-tensioning (internal) tendons failure, as a result of a hit received by the girder by a passing vehicle. The issue was crucial since there are no diagnostic methods available that would enable to evaluate in-situ in a non-invasive way whether the steel cables have been broken.

In order to achieve the scientific goal after the creation of the FEM model, validation tests were started regarding the formulation of appropriate boundary and initial conditions. The morphology of the girder damage inventoried at the site was treated as the reference state for these tests (Fig. 5.14).

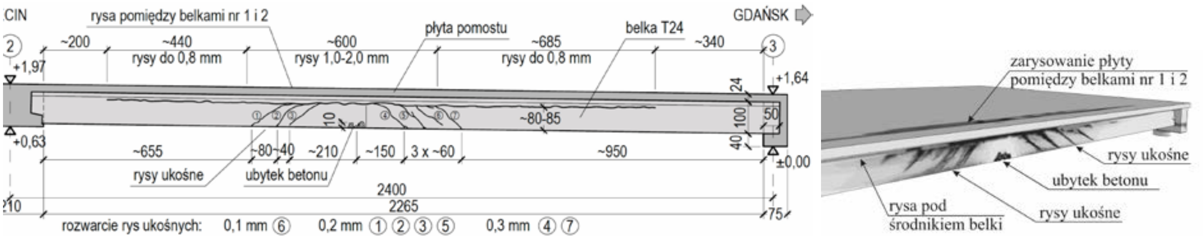


Fig. 5.14. WD-113 viaduct: inventoried damage (left), damage patterns estimations obtained as a result of FEM simulation (right)

On the basis of these tests, the nature of the impact was identified, i.e. direction perpendicular to the axis of the structure at the speed of 50 km/h of a vehiclehaving a mass of ~18.8 t. During such an impact, the patterns of actual and simulated damage are similar. In this case, force in the pre-tensioning girder cables experienced a maximum value of 199.6 kN at 0.01 s. In view of the ultimate force of 279 kN, that can be sustained by the cables, it was assessed that the breaking of the tendons and the failure of concrete beams did not occur and therefore the bridge can resume service, after some appropriate surface repairs.

In [Z4.II.E.b.3, Z4.II.L.b.17] structure aerodynamics problems were considered. The wind pressure distribution on the non-standard construction of the Palm House rotunda in Gdańsk Oliwa (Fig. 5.15, left) were estimated. The calculations were supposed to dispel doubts whether it was correct or not during the design to estimate the impact of the wind assuming that the construction, geometrically resembling a circular saw with teeth (Fig. 5.15, right) was treated as a circular cross-section.

For this purpose, a spatial FEM model of the entire structure was created (Fig. 5.15, middle). However, due to the complex geometry of the Palm House (and related, unacceptable to the client, computational costs) CFD simulations were limited to the analysis of representative 2D planar tasks. CFD calculations were performed using the finite volume method (Fig. 5.15, right).

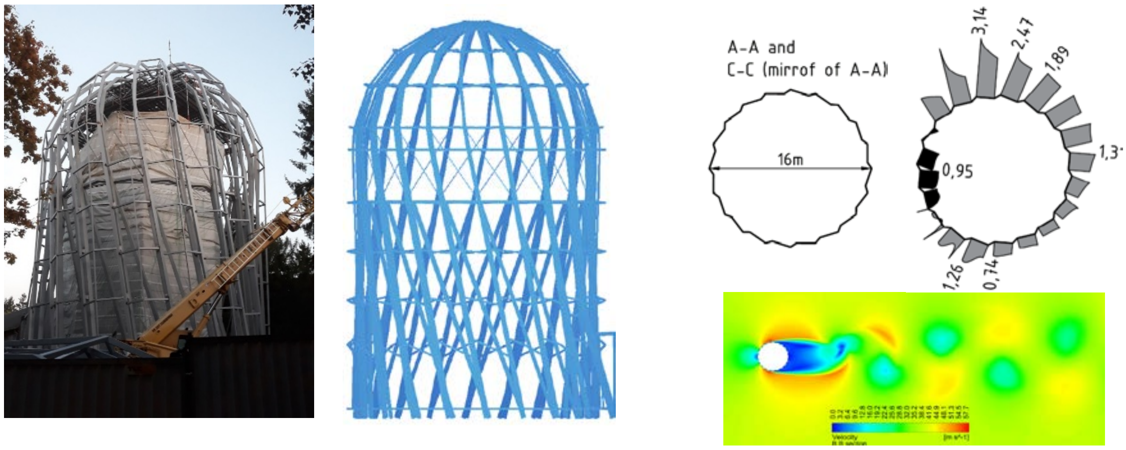


Fig. 5.15. Palm house rotunda: construction works photographed on 10.2018 (left), visualization of the global FEM model (middle), shape of the structure cross section at 1/3 of its height, pressure distributions for an analysed section and velocity contours depicting turbulences caused by the wind estimated by CFD (right)

The conducted simulations revealed, among others, the occurrence of strong local accumulations of the wind pressure values in the corners of the analyzed section of the Palm house. Obtained local values were ~ 1.8 times higher than the ones observed around the perimeter of the circular cross-section.

Technical monitoring systems

My work on the technical construction monitoring systems plays an important role among my achievements. The experiences gained within the framework of the completed PhD dissertation [Z4.II.A.2, Z4.II.E.c.1] resulted in participation in the development of designs, execution and the possibility of analyzing the results of the behavior of structures registered with 19 different types of monitoring systems. Some of them were supposed to provide only information for a short period of time, e.g. [Z4.II.E.e.17], while others to control the safety of the structure during its entire lifetime, e.g. [Z4.II.E.a.7, Z4.II.E.a.2, Z4.II.E.a.8]. It should be noted that each of the designed and implemented systems has been adapted to monitoring tasks and the type of construction. Among other things, it was required to develop individual programs filtering mass signals, as well as their data acquisition techniques. The most interesting systems are presented in Annex 4 pt. 2.

The technical monitoring system of the suspended footbridge in Radom consists of a measurement, expert, and notification modules [Z4.II.E.a.2]. The measurement module is designed to collect information from the points, shown in Fig. 5.16, i.e. meteorological station, accelerometers installed on the lines and the deck, and inclinometers allowing indirect measurement of structural displacements. The expert module is equipped with algorithms that continuously analyze measurement data and determine the state of the structure using appropriate indexes. The messaging module is equipped with a GSM modem that sends results to a dedicated website.

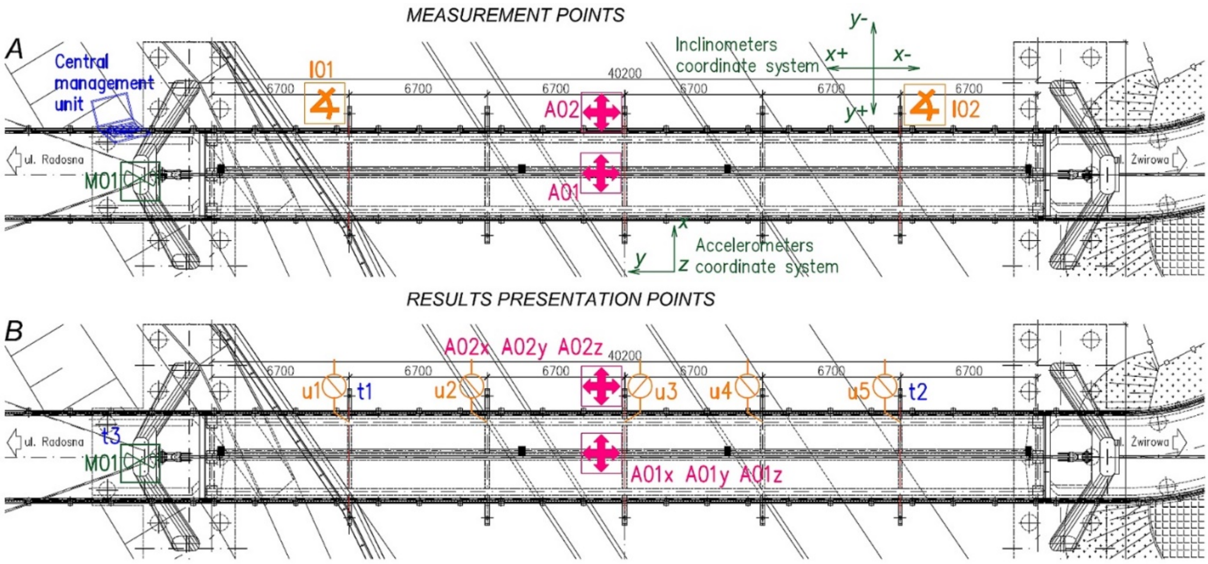


Fig. 5.16. Footbridge in Radom. Monitoring system measurement points (A), result presentation points (B)

The system enables a constant view of the measured parameters, constituting a reliable source of data on both the condition of the structure and the impact of the existing weather conditions on it. The graph in Fig. 5.17 presents changes of structure displacements registered between February 2017 and March 2019. The influence of atmospheric conditions related to the seasons and the moment of rapid change in the geometry of the structure, that occured in June 2018, are both visible. The reason of this change was a move along the main cable of one of the hangers support.

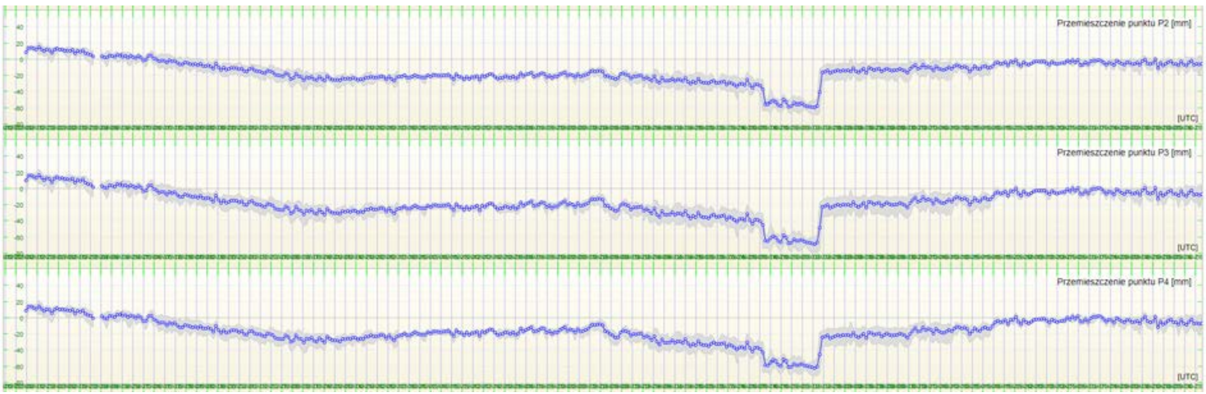


Fig. 5.17. Footbridge in Radom. Monitoring resutls of changes in displacements at the points u2 (P2), u3 (P3), u4 (P4) between February 2017 and March 2019

The technical monitoring system of the cable-stayed bridge over the Wisłok River in Rzeszów consists primarily of standard, for the analysis of this class of problems, modules and measuring sensors (Fig. 5.18) [Z4.II.E.a.7]. A new original solution included implementation of a bridge state computational simulation module [Z4.II.A.2, Z4.II.E.c.1], ultrasonic concrete monitoring module [Z4.II.E.a.7] and measuring forces in cable-stays.

The simulation module was based on FEM model of the structure, validated in the under static loads and dynamics excitations (Fig. 5.18). Its incorporation into the system makes it possible to check the behaviour of all bridge elements. The program, based on the measurement reference data, performs FEM simulations and verifies whether the actual object response is consistent with the calculated one. If not, the system sends a message about the possibility of a failure and the need of structure inspection.

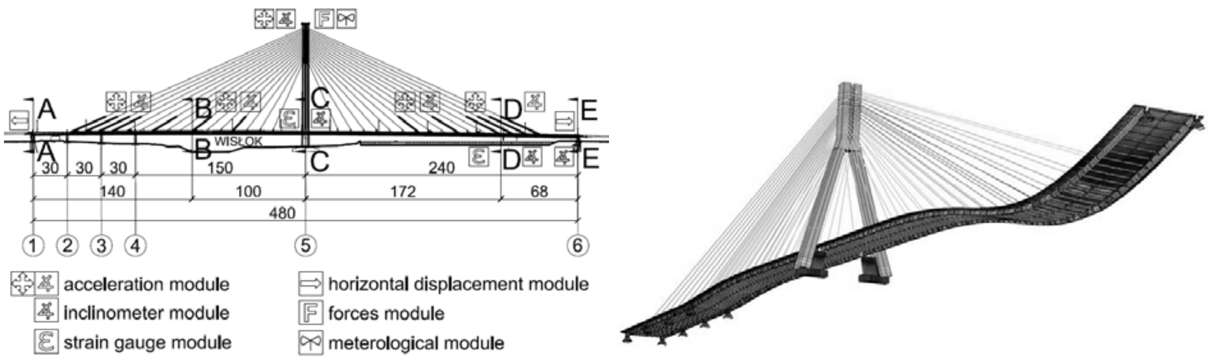


Fig. 5.18. Bridge in Rzeszów: location of measuring points (left), first form of natural vibrations (right)

The identification of forces in cable-stays is carried out using the vibration method, in which the measurement takes place indirectly by converting its value based on the measurement of the cable natural frequency. Such a system, apart from the possibility of controlling the change in the value of force in the cable, gives a direct measurement of vibrations and hence the assessment of the correctness of the cable dynamic response. These measurements were the basis for the selection of cable dampers. In accordance with the recommendations of the suspension system supplier, due to the bad damping characteristics, all the cables should have been equipped with vibration dampers. However, a decision was made consciously, after a representative period of monitoring of the bridge, to install the dampers only on the selected cables. It turned out that the risk of excessive vibration could only affect the longest cables and the installation of dampers was recommended only on them.

5.2. Activity related to completed design, construction and technological achievements, research works, expert opinions and research projects

Data on activity in the achievements of design, construction and technological research activities, expertise and research projects along with representative examples of activities undertaken, a description of my participation and contribution are presented in Appendix 4 in points II.B, II.F, II.J. The activity concerned:

- designs of assembly arch, cable-stayed and suspension bridges (5 totally, 4 after doctorate),
- designs and implementation of technical monitoring systems (20 totally, 19 after doctorate),
- application of solutions developed as part of scientific and research activities in industry (117),
- implementation of the composite pedestrian bridge,
- scientific supervision of 8 tasks related to the design or construction of engineering structures - bridge structures (7), including a crosscut through the Vistula Spit, construction of the palm house in Gdańsk Oliwa,
- performing scientific and technical expertise in the field of engineering structures (85),
- carrying out designs, examinations and reports during test loads of bridges (302 totally 154 after doctorate),
- participation in 4 grants. In one, concerning the composite span of the pedestrian bridge, I was co-author of the application for co-financing, the main contractor. I also administrated and coordinated the implementation of all tasks.

5.3. Parametric summary of scientific achievements

A detailed list of all the published scientific and professional works is presented in Appendix 4. Tables 1-3 include a summary of my scientific and research activity, including the total number of achievements (Table 1) and number of points according to the list of Ministry of Science and Higher Education (MNiSW) for publications after granting of the doctorate included in the scientific achievement (Table 2) and other (Table 3).

The total number of points for publications after the doctorate, taken into account by the MNiSW in research unit assessment, equals **676** (841)* points. Taking into account the participation of the author of the application the total number of points is equal to **317,9** (376,1)* points. Total Impact Factor for publications in which the Applicant was the co-author is **22,401** according to the year of publication (23,131 from 5 years)

Table 1. Summary of scientific achievements (according to Appendix 4 – as of 28 March 2019)

Type of achievement	Total number of achievements	Designation according to Appendix 4	Number of achievements after doctorate
Publications constituting a scientific achievement: - papers in journals from the Journal Citation Reports (JCR) database, - papers indexed in Web of Science (WoS) database, - reviewed articles.	5 7 1	IB IB IB	5 7 1
Papers in journals from the Journal Citation Reports (JCR) database	5	II.A	5
Papers indexed in WoS database	9+(11)*	II.E	9+(11)*
Monographs	2	II.E	2
Chapters in monographs	6	II.E	3
Scientific publications in journals from the MNiSW B list	28	II.E	22
Total number of publications	**63 (74)***		**54 (65)***
Papers presented at international conferences	30	II.L	29
Papers presented at national conferences	38	II.L	23
Total number of the MNiSW points (in the year of publication)	**676(841)***		**676 (841)***
Total Impact Factor (in the year of publication)	**22,401**	II.G	**22,401**
Number of citations according to the WoS database	**146 (74)’**	II.H	**146 (74)’**
Number of citations according to the Scopus database	194 (118)’	II.H	88
Number of citations according to the Google Scholar database	344	II.H	-
Hirsch index according to the WoS database	**8**	II.I	**8**
Hirsch index according to the Scopus database	8	II.I	8
Hirsch index according to the Google Scholar database	11	II.I	-
Design, construction and technological achievements	307	II.B	158
Applications and implementations	138	II.B	137
National patents granted	1	II.C	1
Utility designs	3	II.D	3
Completed research works, expert opinions and other commissioned reports	93	II.F	84
Participation in national research projects	4	II.J	4
Scientific awards	5	II.K	5

*- the publications await entry in the WoS database, the values take into account indexation in the WoS database
’ – number of citations without self-citations

Table 2. The Appendix Z4 point I.B publications statistics according to the MNiSW list (scientific achievement, as of 28 March 2019)

Publication	MNiSW points	Miśkiewicz M. share [%]	Miśkiewicz M. points	IF_{2017}	$IF_{5\ years}$
I.B.1	15	50	7.5	-	-
I.B.2	15	60	9	-	-
I.B.3	20	55	11	0.763	0.816
I.B.4	15	70	10.5	-	-
I.B.5	45	50	22.5	4.92	4.858
I.B.6	15	50	7.5	-	-
I.B.7	15	50	7.5	-	-
I.B.8	3	50	1.5	-	-
I.B.9	15	50	7.5	-	-
I.B.10	15	80	12	-	-
I.B.11	30	80	24	0.622	0.598
I.B.12	20	55	11	0.763	0.816
I.B.13	20	80	16	0.763	0.816
Total	243	average 60	147.5	7.831	7.904

Table 3. The Appendix Z4 point II.A I II.E publications statistics according to the MNiSW list (other achievement after doctorate, as of 28 March 2019)

Publication	MNiSW points	Miśkiewicz M. share [%]	Miśkiewicz M. points	IF_{2017}	$IF_{5\ years}$
II.A.1	40	5	2	4.101	4.451
II.A.2	30	100	30	2.311	2.088
II.A.3	30	10	3	2.475	3.014
II.A.4	45	10	4.5	4.92	4.858
II.A.5	20	35	7	0.763	0.816
II.E.a.1	15	45	6.75	-	-
II.E.a.2	15	50	7.5	-	-
II.E.a.3	15	40	6	-	-
II.E.a.4	15	35	5.25	-	-
II.E.a.5	15	35	5.25	-	-
II.E.a.6	15	33	4.95	-	-
II.E.a.7	15	20	3	-	-
II.E.a.8	15	20	3	-	-
II.E.a.9	15	33	4.95	-	-
II.E.b.1	15	40	6	-	-
II.E.b.2	15	10	1.5	-	-

Publication	MNiSW points	Miśkiewicz M. share [%]	Miśkiewicz M. points	IF_{2017}	$IF_{5\ years}$
II.E.b.3	15	10	1.5	-	-
II.E.b.4	15	60	9	-	-
II.E.b.5	15	20	3	-	-
II.E.b.6	15	45	6.75	-	-
II.E.b.7	15	50	7.5	-	-
II.E.b.8	15	25	3.75	-	-
II.E.b.9	15	55	8.25	-	-
II.E.b.10	15	40	6	-	-
II.E.b.11	15	33	4.95	-	-
II.E.c.1	25	45	11.25	-	-
II.E.c.2	25	100	25	-	-
II.E.d.1	5	30	1.5	-	-
II.E.d.2	5	10	0.5	-	-
II.E.d.3	5	50	2.5	-	-
II.E.e.1	3	40	1.2	-	-
II.E.e.2	5	45	2.25	-	-
II.E.e.3	8	85	6.8	-	-
II.E.e.4	3	40	1.2	-	-
II.E.e.5	8	50	4	-	-
II.E.e.6	8	80	6.4	-	-
II.E.e.7	3	45	1.35	-	-
II.E.e.8	3	50	1.5	-	-
II.E.e.9	8	30	2.4	-	-
II.E.e.10	8	80	6.4	-	-
II.E.e.11	8	30	2.4	-	-
II.E.e.12	3	20	0.6	-	-
II.E.e.13	No points in the year of publication	60	-	-	-
II.E.e.14		20	-	-	-
II.E.e.15		20	-	-	-
II.E.e.16		33	-	-	-
II.E.e.17		33	-	-	-
II.E.e.18		10	-	-	-
II.E.e.19		17	-	-	-
II.E.e.20		80	-	-	-
II.E.e.21		10	-	-	-
II.E.e.22		10	-	-	-
Total	598		228.6	14.57	15.227

6. Information on didactic and organizational achievements and activities popularizing science

Data on activity in didactic achievements, scientific cooperation, national or international internships and activities promoting science are presented in Appendix 4 in chapter III. In table 4 a summary of achievements in this field is presented.

Table 3. Summary of didactic, organizational and popularising achievements (according to Appendix 4 – as of 28 March 2019)

Type of achievement	Total number of achievements	Designation according to Appendix 4	Number of achievements after doctorate
Participation in European and other international or national projects	3	III.A	3
Participation in international and national scientific conferences	70	III.B	54
Assistance in organising committees of international and national scientific conferences	3	III.C	3
Received awards and distinctions	11	III.D	6
Participation in consortiums and research networks	8	III.E	8
Leadership of projects realised in cooperation with business companies	2	III.F	2
Participation in editorial and scientific committees of journals	0	III.G	0
Membership in scientific organisations and societies	3	III.H	3
Achievements in the field of didactics and popularisation of science	8	III.I	8
Dydactic achievements: - number of supervised BSc theses (awarded) - number of supervised MSc theses (awarded)	22 (1) 28 (2)	III.J	22 (1) 28 (2)
Scientific assistance in doctoral procedures as an auxiliary supervisor	2	III.K	2
National and international internships	4	III.L	2
Completed expert opinions or other commissioned reports	421	III.M	269
Membership in expert teams and scientific contest juries	92	III.N	92
Peer reviews of articles: - for journals from the JCR list - for international scientific conferences	2 8	III.P	2 8