Załącznik 4 (Appendix 4)

Summary of achievements (summary of auto presentation)

1. Name and surname

Beata Stankiewicz

2. Diplomas and degrees

Master of Science

Faculty of Civil Engineering, Gdansk University of Technology, a 5-year degree, specializing in bridge structures, 03.07.1987. Thesis: *"The project of prefabricate concrete viaduct with two continues spans"*. Supervisor Prof. Zygmunt Kozakow.

Doctor

Faculty of Civil Engineering, Opole University of Technology, technical sciences, 27.04.2005. Thesis: *"The estimation of noise level in area near various steel and rail bridge structures"*. Supervisor: Prof. Zbigniew Mańko, reviewers: Prof. Barbara Szudrowicz, Prof. Zbigniew Engel.

3. Employment history research units

01.11.1987 – 30.08.1998 – engineer in Department of Concrete Bridge Structures, Faculty of Civil Engineering, Gdansk University of Technology.

15.01.200 – 27.04.2005 – research and teaching assistant in Department of Bridge Structures, Faculty of Civil Engineering, Opole University of Technology.

27.07.2005 – now – assistant professor in Department of Road and Bridge Structures, Faculty of Civil Engineering, Opole University of Technology.

4. Indication of achievement resulting from art 16 paragraph 2 of the Act from March 14, 2003 academic degrees and academic titles and on degrees and title in art (Dz.U., item. 595 with changes)

4.1. Title of scientific achievement

The implementation of composites created by glass fibers (GFRP) in bridge decks.

4.2. Author, monograph title, year, publisher

Stankiewicz B., *The implementation of composites created by glass fibers (GFRP) in bridge decks,* Monographs z. 430, Opole University of Technology, Opole 2015. Reviewers: Prof. Janusz Szelka, Prof. Sylwester Kobielak

4.3.Main description of the scientific purpose and obtained results

In modern material engineering, fiber-modified construction plastics play an important role. Materials based on fibers placed in a polymer matrix are a new technological opening in shaping light, durable structural elements in general construction, but also in bridge construction. CFRP (Carbon Fiber Reinforced Polymers) or GFRP (Glass Fiber Reinforced Polymers) materials are already widely used in reinforcement and modernization systems and are increasingly used as a structural material. The development of glass fiber production lines and the comprehensive technological capabilities of the production of modern epoxy and polyester polymers have generated novel construction systems, different in terms of properties, from the mechanics of traditional materials. The bridge element is the structural element of the bridge structure that is destroyed first. Its corrosion causes degradation of consecutive structural elements and, as a result, decreases the bearing capacity of the object. In addition, along with the development of transport, requirements for the load-bearing capacity of objects increase, therefore even buildings in a satisfactory technical condition require modernization. The costs of such repairs are usually very large. It is now popular to use carbon fiber tapes and mats to reinforce load-bearing elements - reinforced concrete girders or slabs. However, there are limits to lifting the load capacity in this way. You can reduce the weight of the structure by replacing the traditional heavy reinforced concrete slab with a lighter composite. Bridging composite panels can be used in temporary bridge constructions used in civil and military buildings. An additional justification for comprehensive research on the use of polymer composites in bridge engineering is the fact of their implementation in mobile military bridges (eg bridge slabs in the American Coruposite Army Bridge system - CAB), from which high strength is required. They have to be lightweight because they are transported by air, and at the same time they are adapted to the weight of tanks with a weight of about 70 tons. The interest in GFRP composites results from two basic premises: the first - their excellent mechanical and strength parameters, and the second - it is a small own weight. The simultaneous combination of these features occurs in principle only in the case of composites, hence the rapidly growing in recent years their use in constructions for which this compilation is of paramount importance. The macroscopic features of the composite depend in a clear way on its internal structure and in particular on the orientation of the fibers, their distribution in the cross-section of the composite and the homogeneity of the fiber's properties. The internal structure of the fiber material depends, however, directly on the technological process, and in principle on strict production disciplines and quality control. The general advantage of using fibers results from their high stiffness and strength, many times greater than the values of the corresponding characteristics for the material from which the fibers were made, but determined on the basis of tests of this material. There are two basic types of glass fibers – E and S, with different mechanical properties: strength, fatigue, impact, thermal and rheological. From the point of view of the strength properties of a composite, more effective in its structure are continuous filaments that run in the layer in one direction. Glass fiber reinforced polymer composites (GFRP) are characterized by very high specific strength, towards sunken fibers, and their additional features are, among others, durability, resistance to atmospheric and chemical factors and high material damping of vibrations. Polymer composites are currently an innovative research area and this fact is reflected in currently developed scientific projects and in innovative, constantly improved technological systems. Materials engineering strives to meet the very important durability parameters of construction materials and hence the pressure of research on composites, including GFRP. In Polish conditions, the topic of the possibility of implementing GFRP composites in bridge constructions has not been described in any previous monograph (2015). The aim of the dissertation "The use of glass fiber-based composites (GFRP) in bridges structures" is to broaden and deepen the knowledge about the morphological structure of GFRP composites that can be used in the modular orthotropic plates of bridge structures. Another synthetic plane, presented in the monograph of knowledge, is the determination of strength parameters of GFRP and comprehensive analysis of mechanisms of destruction of composites, whose nature differs from the methods of destruction of traditional materials. An important cognitive area of research is the determination of effective research methods for the characteristics of the GFRP and comprehensive analysis of mechanisms of destruction of composites, whose nature differs from the methods of destruction of traditional materials. An important area of research cognition is the determination of effective testing methods of GFRP strength characteristics for bridge applications and an effective register of changes in the composite microstructure, leading to delamination of the material. The publication contains 10 thematically consistent chapters. The first chapter is the general characteristics of FRP composite materials. Chapter II presents the results of own research of the selected GFRP composite. Chapter III presents examples of bridge structures with composite decking. Title IV of the chapter is the design and research process of GFRP bridge plates in the analysis of J. Knippers and M. Gabler from the University of Stuttgart. Chapter V describes the numerical model of the ASSET Fiberline module, according to the author's analysis. Chapters VI and VII present, in turn, the results of American research on GRFP plates of the DuraSpan system and the GFRP module studies according to Herbert Gurtler. Chapter VIII describes the use of GFRP and other FRP composites for reinforcement of bridge pillars. Chapter IX is devoted to the mechanisms of destruction of composites along with the analysis of the results of their own strength tests, enriched with the scanning observation of the composite microstructure, in the process of delamination. Chapter X presents the assumptions for the design concept of a footbridge with a composite platform along with the results of the author's comprehensive numerical analysis. Our own internal structure investigations confirmed the anisotropic structure of the selected GFRP composite (Fiberline). They characterized in detail the morphology of a construction material composed of ECR glass fibers and a polymer matrix, as a mixture of separated polyester and epoxy resins. The arrangement of fibers in the composite is relevant to the strength parameters of the GFRP elements. This statement should be considered as a research thesis, which is confirmed by the author's analyzes. A thermal differential analysis of DTA was carried out for the selected fibers, which indicated a high value of dilatometric softening temperature T_d = 8520 ^{0}C. The results obtained prove the high durability of glass fibers placed in the composite. This factor undoubtedly affects the durability of the overall composite. As a complementary study, the EDAX analysis was performed to confirm the chemical composition of the glass fiber separated from the composite. Using SEM scanning microscope, observations of morphology, habit and mutual positioning of glass fibers in the matrix were carried out.

A Fourier's infrared spectroscopy was used to identify the type of the matrix, i.e. the material enabling the fiber to be bonded to the surface elements constituting the basis for the production of structural elements. On the basis of infrared IR spectrum analysis, it was found that the matrix material belongs to the class of thermosetting plastics. Bands occurring in the range from 3084-2586 cm^{-1} are characteristic for both epoxy and polyester resins, while the band lying at 1734 cm-1 for polyester resin. The absorption band at 1734 cm^{-1} corresponds to stretching tensile C = O ester group, while the absorption band appearing at 3447 cm^{-1} corresponds to the stretching vibrations of the OH group of the alcohol group. Two absorption bands at 2930 cm^{-1} and a band at 2856 cm^{-1} correspond to symmetric oscillations of the group = CH_2. It can be concluded that the fiber matrix is a mixture of an epoxy resin cross linked with an amine based on bisphenol A and a polyester aliphatic resin based on unsaturated polyester. The matrix provides a protective coating for the fibers, as well as to some extent involved in the load transfer that the GFRP composite is subjected to. The completed DTA analysis for separated fibers was compared and supplemented later with comprehensive DSC analysis. As part of their own material analyzes, a laminate test was carried out based on glass fibers embedded in a mixture of epoxy and polyester resins (GFRP Fiberline HD) by performing DSC differential scanning calometry. The dynamic measurement was carried out in the flow system in the METTLER DSC apparatus. The DSC technique was used to measure thermal power, and more specifically change the difference in thermal flux generated between the test and reference samples during thermal transformation. Dynamic mechanical analysis (DMA) was also performed, which was used to measure the mechanical and viscoelastic properties of the material as a function of temperature, time and frequency, during periodic changes in the load to which the sample is subjected. The test for the laminate sample (GFRP Fiberline HD) was carried out using a METTLER TOLEDO DMA / SDTA861e, which allows a very accurate determination of the size of the module elasticity. The results of the DSC and DMA analysis became the basis for an important scope of the monograph, devoted entirely to aspects of material durability, which is GFRP Fiberline, used for use in bridge plates. The strength tests of bending and stretching of material samples in the ISTRON ARAMIS device were performed, with microscopic observation of the phenomenon of delamination of the composite (KEYENCE VHX-5000 microscope). The use of DTA, DSC and DMA analysis was used to determine the thermal and mechanical stability of the tested composite as important features in the aspect of material durability. Based on the DSC analysis, it was shown that the GFRP material (obtained from the Fiberline HD platform) is thermally stable and resistant to temperature changes, in the wide range from -50 °C to + 300 °C. Its composition has the advantage of an amorphous phase. On the basis of the DTA analysis for ECR glass fibers (separated from the Fiberline HD GFRP composite), the transformation temperature T_g was determined to reach 703^0C. For the composite (fibers plus polyester and epoxy resin) the endothermic transformation temperature was determined at 255^0C. The DSC analysis performed is complementary and valuable, in terms of comparison, how the ECR glass fibers are resistant to the influence of increasing temperature in relation to the durability of the composite. Thermal differential analysis DTA and differential scanning calorimetry, flow type DSC and DMA tests is a modern standard of material testing. In the thermal dynamic analyzes performed, the temperature of the samples changed in a linear manner. The combination of different methods of thermal analysis turned out to be valuable in order to make a comprehensive, comprehensive material check. The research used high-class research equipment, the best in the ranking of scientific units in Poland 2014-2015 (equipment available at AGH in Krakow and at the Faculty of Chemistry at the Rzeszow University of Technology, Opole University of Technology does not have this type of research capabilities). The results of material tests of DTA, DSC and DMA composite GFRP (Fiberline system), for bridge applications in bridge plates, were first described in Poland, in the presented monograph and other publications related to each other subjectively [M1] - [M21]. Strength testing of GFRP material showed very good strength parameters of the axially extended composite element (cut from the Fiberline HD platform plate module), composed of glass fibers and epoxy and polyester resins. The element was destroyed when the tensile stress reached the value of ≈ 300 MPa. The tests also proved very good strength parameters of the bending composite element (cut from the Fiberline HD platform plate module). The bending stress of ≈ 267 MPa corresponded to the destruction of the element in the 4-point bending test. DMA analysis, however, proved the thermal stability of the sample and high values of the conservative module. The tests took into account the vibration frequency of the 5 Hz composite, the value of the applied force is 2N, the dimensions of the tested sample 70 x 10.22 x 3.44 mm. As confirmed by the research, the value of the conservative module increased with increasing temperature. At a temperature of 50 °C, it reached a high value of 20600 MPa. The selected temperature range has been adapted to the hypothetical conditions of the actual work of the structure, with the participation of the polymer composite. Generally, isothermal studies have proven high values of the conservative module, in a wide temperature range from -30 °C to + 50 °C. The technical suitability of polymeric materials depends on whether they meet the requirements of stiffness and strength, so that their durability under conditions of use is sufficient. Traditional mechanical characteristics obtained as a result of static, tensile, compressive and twisting tests are insufficient to predict the behavior of polymeric materials under extreme conditions of use (eg high and low temperatures) as well as in the long term. The problem is therefore the choice of test methods that allow to predict the change in viscoelastic properties as a function of time based on experimental data. The Young's modulus E determined by the DMA (Dynamic Mechanical Thermal Analysis) method is a M * complex module (E = M, according to the METTLER apparatus, described by the equation M * = M '+ M''. It consists of the real part M' (module conservative), occurring in accordance with the phase of deformation, and imaginary M '' (loss modulus), which is shifted relative to the deformation of π/2. Frequently, instead of the loss modulus M '', the tangent of the mechanical loss angle tgδ is given. In the case of perfectly elastic bodies M '' = 0, on the other hand, for perfectly viscous bodies M '= 0. Generally M'<M'' for polymers and composites on a polymer matrix,. The Young's modulus obtained in the own research, for the laminate sample (GFRP Fiberline HD) in the real part, i.e. the conserving module - M ', reached the value in the hourly cooling or hour heating of the sample, respectively:

• Temperature -30^{0}C, M ‘= 14000 MPa,

• Temperature – 5^{0}C, M ‘= 18200 Mpa,

• Temperature + 50^{0}C, M ‘= 20600 Mpa.

The examples of the existing road bridges and pedestrian footbridges cited in the monograph confirm the general thesis of publication considerations, which boils down to the statement that the GFRP composites, produced in pultrusion technology, in the form of modular elements can replace elements made of traditional materials such as concrete and steel, and they can be used as a platform slab system or as structural elements of modern, light, easy to assemble, architecturally interesting bridge structures with small and medium spans of theoretical spans. The emerging question of a scientific-construction-research nature is an issue concerning the durability of the structural material itself, during the actual operation, durability of connections between GFRP modules and durability of the overall structure, subjected to static and dynamic loads. The comprehensive GFRP Fiberline modular system described in the monograph of research and analysis verified the author's material tests as well as strength and numerical tests. The research undertaken confirmed the research thesis that the GFRP composite (Fiberline) is a predisposed material for bridge applications (bridge plates), as it exhibits durability at all operating temperatures. Of course, DSC and DMA analysis would be valuable for the aged material acquired from the bridge slab, which has been in operation for many years. Such research is planned in the further scientific activity of the author of the publication. A very important department of mechanics of composites is the mechanics of destruction. The composite, with a complex structure, undergoes a complex destruction process, and at the same time is able to carry the load long after the first signs of damage appear. In the damage, we can distinguish scratching of the matrix, breaking the fiber or cutting the fiber and matrix. To identify the origin and development of this type of damage, macro models based on criteria for the strength of the orthotropic layer are used, and their task is to accurately reflect the complicated mechanism of destruction in this heterogeneous material. The more fluid modification of material properties with the occurrence of damage, until complete destruction is the subject of the mechanics department entitled continuum damage mechanics (CDM). This approach involves the introduction of a parameter called destruction, which depends on the deformation or stress and it takes values from zero for material without damage to one for the material completely destroyed. The virtual crack closure technique (VCCT). This approach, like other crack-based mechanics (virtual extension of the cracks, J-integral) requires the existence of a crack and is only able to model its dissolution Nevertheless, this topic is still open to new ideas of researchers, and this is mainly related to the complex internal structure of composites and what is associated with a difficult to predict and describe the mechanism of destruction while at the same time quite a long "lifespan" despite damage. An important aspect is also the development of damage due to further load, up to the total loss of load capacity by the structural element. The process of destroying composites can have a different course depending on the type of composite and the load on it. In general, destruction of a composite in a mechanical sense is a significant change in material properties that is dangerous for the structure. Before the destruction takes place, the composite often becomes damaged, which is not always dangerous for the construction, but they cause a change in the mechanical properties of the composite, usually its weakening, which should be taken into account in the design process. An important element is identifying the damage and modifying the properties of the material with damage. The type of damage depends mainly on the mechanical properties of the components, in the case of fiber composites - warp and fibers, as well as on the type of their bonding. In the case of a single lamina, there are damages inside the intralaminar failure structure and the following types of damages occur: cracking of the matrix, tearing cracking or buckling of the fiber, removal of the fiber from the matrix (loss of adhesion), shearing of the composite. In order to determine the place of origin and type of damage, some characteristic values are necessary which determine the limit states of the material. These sizes can be both strains and stresses, characterizing the limit state of the material. Determining the critical stress values with their complex state, which we deal with during operation, is extremely complicated and would require an enormous amount of experiments for various possible load sets. It should be noted here that in the case of fiber composites, these critical values are different in different directions and depend on the way the fibers are arranged. The GFRP composite material embedded in the bridge plate is exposed to dynamic influences resulting from the operation of the bridge structure. In this aspect, the fatigue strength of composite modules is important, as well as the analysis regarding the existence of early delamination in the structure of the bridging laminate. Observation of the material for early delamination and subsequent progressive delamination is very important during the monitoring of the bridge structure, with a composite bridge plate or other structural elements from GFRP. The micro-scratches are distinguishable, followed by scratches in the direction perpendicular to the applied external load and micro-scratches and scratches parallel to the laminated fibers, i.e. the defects which appear in the matrix of the composite in the direction of the fiber pultrusion axis, as well as the advancing features laid at an angle of 450 between the fibers. Early delamination is initiated by the formation of a crack in the matrix between the fibers, but also at the interface of the matrix and the fiber. The microscopic analysis described in the monograph, the internal microstructure damaged in the material strength tests carried out, showed a zone loss of fiber and matrix bond and glass fiber breakage, first of all in the side zones of the composite. The middle core of the composite, composed of densely packed glass fibers in a parallel system, proved to be the most durable. In their own publications on the subject of GFRP applications in bridging, the directions of the possibility of modifying GFRP composites were presented in order to limit micrographic projections occurring in the polymer matrix between the fibers. These micrographs are generally the initiation of early delamination, observed in the micro scale. In the monograph, the directions of possible modifications of GFRP composites were presented in order to limit the microspheres occurring in the polymer matrix between the fibers. The modification and refinement of the polymer matrix using nanoparticles, for example nanosilica or carbon nanotubes is an innovative approach to composite materials, widely studied in the world, in the aspect of aerospace, construction and military applications. The mentioned issues became the basis of English-language publication of the author of GFRP Bridge panel by material and FEM analysis, published by Lambert Academic

Publishing, Germany 2015 [M5]. Innovative, in the undertaken research activities, was the combination of macro and micro scale in the conducted deliberations. Modern composite materials, including GFRP, are characterized by other mechanisms of destruction, from those that occur in the destruction processes of traditional materials. Composites are important for scanning by means of scanning microscopy, which are used to describe the phenomena of delamination. In the research procedure, the SEM scanning analysis and electron microscopy was an important complementary field of cognitive activity. The topic of the origin of early delamination of GFRP bridge modules has been presented in proprietary conference publications at the global cyclical conference MechComp 2014 Long Island, in 2014 [C7], and at the world congress Spring World Congress on Engineering and Technology (SCET 2015) in Beijing, in 2015 [C5]. For bridge constructions in which we define a GFRP composite platform, the analysis of dynamic influences is important and interesting for scientific and engineering reasons. In general, the issues of dynamics include at the same time three basic aspects: a description of dynamic interactions, dynamic features of materials, especially the load bearing structure, but also a bridge and interaction between interactions and structure. The monograph presents the results of research and analysis of dynamic influences on the construction of a footbridge, with a lightweight composite platform GFRP HD Fiberline.

Numerical analyzes included modal analysis and pedestrian crossing in various construction configurations, various static schemes, bearing systems, etc. The main objective of the analysis was to check the conditions of the use of composite GFRP decking, in terms of determining the value and form of natural vibrations. Comprehensive numerical verification of the footbridge with a composite platform, presented in the monograph, is the first stage of the conceptual and design trend, the use of GFRP bridges in footbridges. The obtained results of modal analysis and structural response to pedestrian crossing were presented at the global cyclic conference Footbridge 2014, London, in July 2014 [C4]. In further phases of the activity, an analysis of the dynamic work of a pedestrian footbridge with a suspended structure with an GFRP bridge was carried out. In the prospective study, a renovation project will be developed, combined with the modernization of the bridge structure, in which the old bridge plate will be replaced by a light composite board. For this building, after its completion, tests will be carried out, which ideally are to show how the composite material of the bridge plate is responsible for damping the bridge span. The most important conclusion from the modal numerical analysis (described in the monograph) was that in the construction of a footbridge with a composite platform, set as a two-span system, independently working and freely supported bays were obtained in the first forms of natural vibrations as well as in the case of a pedestrian crossing vibrations below 5 Hz. This value is required (mandatory to obtain) in the analysis of the dynamic work of the footbridge construction, with the overriding objective of ensuring its safety and guaranteeing comfort for users. The obtained results are significant due to the fact that the analyzed structure - a pedestrian bridge can be qualified for slender and flaccid structures, characterized by a small width (usable width 3000 mm, total construction 3440 mm) with a large span - two spans above 24000 mm. Dynamic influences for such objects, their work in the dynamic range is extremely specific. Of course, the low self-weight of the composite deck, which causes the sensitivity of the structure to dynamic impacts, is of additional significance. Stratification of the structure, considered in multithreaded analyzes, resulted in the effect of increasing the natural frequency and frequency of vibrations at the pedestrian crossing, which should be considered as an undesirable phenomenon. At the present level of our own advancement in numerical analysis, it is known that it is very demanding to model the connection between the panel and the bridge supporting beams - steel or concrete. In the case of a glued joint, the need to deeply enter the database that identifies such a connection should be emphasized. Difficulties are encountered in the correct modeling of the bridge, composite board and anisotropic material cooperating with steel or reinforced concrete girders, which is an isotropic material.

In conclusion, the publication expands knowledge useful for bridges about modern technological and design solutions in designing and construction of bridges of road facilities and footbridges, for civil and military purposes. ECR glass fibers are produced in Poland; epoxy and polyester resins are widely available. Perspectival, it is possible to produce Polish GFRP modules for bridge applications using pultrusion technology. At the beginning of the road to the emergence of this technology on Polish soil it is important to learn the morphology of the material, expanding knowledge about the technical, constructional and operational viability of the GFRP composites. The individual chapters of the monograph synthetically showed material analysis, strength tests of GFRP material as such and modules forming bridging plates. All research, own and described based on the achievements of scientific units in the world, confirm the usefulness of GFRP composites in bridge structures. Due to their mechanical properties (high tensile strength and high modulus of longitudinal elasticity), other composites based on CFRP carbon fibers are most often used.

To reinforce bent reinforced concrete constructions, rigid laminates or flaccid mats are used, which are stuck on the surface of the concrete as an external tensile reinforcement. High efficiency of strengthening reinforced concrete elements for bending with the use of composites has been confirmed by numerous domestic and foreign laboratory tests and practical applications on existing facilities. R. Kotynia, pioneer countrywide, carried out comprehensive research towards the suitability of passive and active CFRP reinforcements of reinforced concrete structures in general construction. K. Furtak and T. Siwowski introduced, as the first in Poland, external reinforcement of CFRP lamellas in modernized bridge constructions. Increasingly, material engineering attempts to combine different types of fibers in a polymer composite - an example of a road bridge, made in autumn 2015 near Rzeszow from composite elements of FRP. A pedestrian bridge (a research team of the Gdansk University of Technology and the Military University of Technology) was designed and comprehensively designed with a coating structure made of GFRP sandwich composite with a PET core (the project was never realized). In modernization applications of bridge construction elements, composite materials, reinforcing materials, made of various types of fibers, including glass ones, are combined. In Europe, the leading research unit in the field of composites is the Composite Construction Laboratory at the Swiss Institute of Technology in Lausanne. Various components under the direction of Professor Thomas Keller carry out research projects there, mainly focusing on bridge plates produced by the Danish manufacturer Fiberline. Professor Keller was the first in Europe, based on material research, to show the anisotropic structure of the GFRP composite, composed of a glass fiber conglomerate embedded in a polymer resin. The dissertation, on the other hand, is a comprehensive report on materials research carried out for the first time in Poland, which analyzed in macroscopic and microscopic terms the material cut from the GFRP Fiberline composite panel element. Bridge structures of a construction made entirely of a composite based on GFRP glass fibers are still one of the few. Only a few such structures are known in the world. These include: the Scripps Bridge pedestrian bridge in La Jolla, USA, the Aberfeldy Bridge footbridge in Scotland, the United Kingdom footbridge with the truss Pontresina Bridge in Switzerland, the arch bridge near the Spanish city of Lleida, the footbridge in Tainan at The construction of a suspended footbridge in Kolding, Denmark, was the subject of a co-authored study carried out in 2016 (M18), not described in an earlier in-house monograph from 2015.

The basic modal characteristics of engineering structures are natural frequencies, their corresponding vibrations and structural damping. Knowledge of the actual values of the characteristics is the basis for verifying the correctness of the solutions adopted at the design stage of the structure and can be helpful for the assessment and monitoring of the technical condition of structures subjected to dynamic loads. This is particularly important in the case of structural damping, which is one of the most important and at the same time uncertain parameters, significantly reducing the uncertainty of the computational structural response. A reliable way to determine the real values of dynamic characteristics of a structure is to measure their vibrations. Publications on the study of dynamic characteristics and responses under dynamic load of bridge structures with a structure made of polymer composites based on GFRP glass fibers are still scarce and insufficient to formulate guidelines and recommendations for the design of this type of objects. Therefore, there is now a great need to do such tests. The co-authored analysis presents the method of determination and the results of the analysis of dynamic characteristics of a cable-stayed pedestrian bridge located in the town of Kolding in Denmark, made entirely of a polymer composite based on GFRP glass fibers. On the basis of measurements of free vibration accelerations of the footbridge, forced by jumps of one person, the first five natural frequencies, corresponding to the form of natural vibration and the number of structural damping, were identified. The frequencies and forms of natural vibrations were determined by frequency decomposition. The values of the number of structural damping were determined on the basis of approximation by the method of least squares of filtered vibrations of the free footbridge platform. The obtained values of the damping number were compared with the values given in the literature for selected footbridges with constructions made of other commonly used materials. A relatively large value of structural damping of the analyzed footbridge was found. The obtained test results may be helpful in predicting the dynamic response of the newly designed bridge structures, as well as for the assessment and monitoring of the technical condition of the existing bridge structures of the structure made of composites based on GFRP glass fibers. Measurements of free vibrations of the footbridge were made after two decades of object exploitation. Two low noise sensors type PCB 3711E112G, made in the Micro-Electro-Mechanical System (MEMS) technology, have the ability to record vibration accelerations with frequencies in the range from 0 to 400 Hz in the measuring range of ± 2 g. The acceleration sensors were combined with Data Translation Card DT9837A, and this in turn with a laptop computer, used for constant control and recording of data during the research. To determine the form of vibration, it was necessary to use two sensors simultaneously. For this purpose, 28 measuring points were selected located in the upper part of the supporting beams of the bridge spans ("A" and "B" girders), mainly at 3.1 m intervals along the longitudinal axis of the girders. During the tests, one of the sensors was in a fixed position at the reference point, while the other was placed sequentially from point 1 to point 27. After each change of the position of the mobile sensor, free vibration measurements of the footbridge platform in the vertical plane were carried out during at least 15 seconds, forced by a single jump of one person. The jumps were made in the middle of the bridge near the reference point. Measurements were recorded at a sampling frequency of 200 Hz. Based on the measured accelerations of the bridge vibrations, the frequency of free vibrations of the bridge, which on the axis of the abscissae corresponded to the dominant values in the obtained spectrum, was determined by means of the fast Fourier transform. On the resulting visible spectrum, five distinct peaks were distinguished whose values correspond to the first five frequencies of free platform oscillations, ie: f_1 = 4.30 Hz, f_2 = 6.59 Hz, f_3 = 11.13 Hz, f_4 = 17.4 Hz, and f_5 = 20.23 Hz. In order to determine the natural vibration form of the footbridge analyzed, corresponding to the subsequent natural frequencies, the procedure of the frequency decomposition method known in the world literature under the name Frequency Domain Decomposition (FDD) was applied. The FDD method was developed by Brincker and is an extension of the method known as Peak-Picking. This method is used to determine the frequency and corresponding forms of the own vibrations of the structure based on recorded digital signals representing the vibrations of the structure in at least two measurement points at the same time. For this purpose, it is necessary to determine the distribution by Singular Value Decomposition of the set of G_{xx} spectral density matrix of registered construction responses. The set of these matrices in a finite discrete frequency range should be determined by means of a discrete Fourier transform. The vibrations of the analyzed footbridge were determined based on the results of measurements of vertical accelerations of free vibrations of its bridge, forced by single jumps of one person, registered simultaneously at two different measurement points, i.e. at a fixed reference point and at measuring points from 1 to 27. The calculations were carried out using the author's a computer program written in the MATLAB environment. The PSD and CSD spectral densities of the discrete digital signal, representing free vibrations of the analyzed footbridge, were determined using the Welch technique. The values of the number of constructional attenuation ξ_k of the footbridge of the analyzed footbridge, corresponding to the natural frequency f_{0k}, were calculated on the basis of registered vertical accelerations of free vibrations of the bridge at the reference point. For this purpose, the recorded vibration accelerations were decomposed into five components of free vibrations characterized by the analyzed vibration frequencies from f_{01} to f_{05}. Vibration decompositions were made using a filtration technique using a Chebyshev type 1 band-pass filter, on the order of 8, with a 1 dB waviness coefficient. The filtration procedure was carried out assuming pass band bandwidths in the following ranges: 3.5-5.0 Hz; 6.0-6.8 Hz; 11.0-11.5 Hz; 16-16-17.3 Hz and 19.5-20.7 Hz. On the basis of in-situ tests of a suspended bridge made of structural elements entirely made of GFRP composite, the following conclusions were made: a) the first five natural frequencies, corresponding to the form of natural vibration and the number of structural damping, were identified. Own vibration forms No. 1, 3, 4 and 5 represent the forms of vibrations of the flexible platforms, and the form No. 2 is a torsional form of vibrations,

b) on the basis of a comparison of the obtained values of the damping number of the footbridge and the literature values for selected footbridges made of concrete or steel with comparable spans, it was found that the structural suppression of the bridge made entirely of GFRP composite is the highest and ranges from 1.6 up to 2.8% for all analyzed natural frequencies. The suppression of concrete footbridges ranges from 0.2 to 1.8%, and steel from 0.2 to 2.1%.

Due to the insufficient number of publications regarding the tests of dynamic characteristics and responses under the dynamic load of bridge structures with a structure made of GFRP polymer composites, there is currently a great need for such tests. The information obtained from these studies may be helpful at the stage of designing such new types of facilities in order to verify the calculation models adopted for them and predict their responses under dynamic load, as well as to evaluate and monitor the technical condition of existing facilities. Performed in-situ studies, their analysis and publication effect are complementary to the basic research trend presented in the monograph M1. The monographic publication described the spectrum of application possibilities of composite GFRP platform plates, based on own strength tests, as well as research experience of leading scientific centers in the world, dealing with the problems of GFRP applications in bridge engineering. Using the latest equipment available in Poland, comprehensive research of GFRP Fiberline material was carried out, performing DTA, EDAX, DSC and DMA analyzes. The results of these studies contributed to the knowledge of the morphology of the material and proved the durability of the tested Fiberline GFRP. The work touched on the specificity of the mechanism of destruction of the GFRP composite, analyzing the phenomena in the dimension of electron microscopy. A suggestion of the pedestrian bridge design concept with the GFRP Fiberline HD platform, with the results of modal analysis, became a separate part of the publication. Monothematic monograph in its intentions is a report of a comprehensive scientific-research topic, the use of modular GFRP bridge plates in new and modernized bridge, civil and military structures, with an analysis of their durability, advantage over traditional solutions, checking the possibilities of their recycling. The author's monograph focused on the innovative issues of thermal analysis of the durability of the GFRP composite and the observation of mechanisms of destruction in its microstructure. The multithreaded study was based on research, tests and experimental tests and comprehensive numerical analyzes. The habilitation monograph presents the state of knowledge, the possibility of using GFRP composites in the aspect of bridge constructions, research directions and research methodology, design possibilities in modern structural shaping. The first author's publication published in 2016 in the Journal of Composite Materials is to show a modern research methodology, proving the durability of the GFRP composite material, in an innovative field on the Polish and world scale. Compatible methodology of comparative research and analysis was used for the research process for GFRP composite samples after 20 years of presence in a natural environment in a bridge structure, as described in 2017, also in the Journal of Composite Materials. Comprehensive dynamic tests of the footbridge structure made of 100% GFRP were carried out to confirm the very good technical condition of the footbridge. In addition, confirmation of the need to carry out specific material tests and in situ tests was obtained in order to determine the durability of structural solutions, the effectiveness of the connections of components, and the absence of degradation changes in the material. Thus, a set of principles for monitoring and inventory of composite structures was developed. On the basis of a broad review of the literature, the authors developed their own standards regarding the methodology of composite structures of bridges.

For the greatest scientific achievements of the dissertation, I think:

a) confirmation of the usefulness of instrumental thermal methods and scanning electron microscopy to determine the bridge durability of the GFRP composite and its stability over a wide range of temperatures and to explain the mechanisms of composite destruction,

b) proposing a test procedure for determining the strength parameters of modular platforms with GFRP,
c) comprehensive assessment of the dependence of the technical parameters of the GFRP composite on the anisotropic structure of the fibrous material,
d) detailed verification of own research in the aspect of results obtained by scientists associated in significant research teams in Europe and in the world,
e) checking the possibilities of actual implementation of GFRP boards in Polish bridging and the possibility of production of bridge GFRP composites in Poland,
f) indication of the desirability of using GFRP plates for new bridge constructions and modernized structures,
g) creation of a database for polymer composite for bridge applications, for the purpose of future development of currently non-existent standard recommendations as a design interpretation used in the calculation of bridge constructions involving GFRP.

5. Discussion of other scientific and research achievements

5.1. Before obtaining a doctoral degree

The PhD thesis realized in 2005, covering the multidirectional research of acoustic phenomena in the surroundings of various railway bridges, in order to determine the acoustic climate prevailing in their vicinity and the analysis of factors (such as the type of construction, location) which depended characteristic, determined acoustic parameters. The comprehensive field research undertaken, described and analyzed in the doctoral thesis, was the basis for answering the question how the bridge object, which is a part of the railway, affects the increase of noise level (acoustic pressure), due to vibroacoustic phenomena consisting in a strict correlation of the sound pressure level and the level of vibration acceleration of the steel bridge structure, in selected time sequences, while moving around the rolling stock object.

The supplementary trend of scientific research and published studies was the issue of using acoustic screens on road and railway bridge objects, as well as the subject of the specific nature of multiple reflections of acoustic waves between parallel bridge screens. The problem of fixing screens to the structure of the bridge and defining the acoustic efficiency of their operation, in various configurations, concerning the layout of the bridge-screen object – adjacent area. During the PhD thesis, 2000-2005, the topic of protection against noise in the neighborhood of bridge structures and the use of acoustic screens was poorly recognized and described in Poland. However, after 2005 there was a wide expansion of investment of acoustic screens on roads, on bridges, overpasses and downtown flyovers.

5.2. After obtaining the doctoral degree

The main directions of my scientific and research work, after obtaining the doctoral degree, referring thematically to the subject of the doctoral thesis are issues related to the problem of ways to reduce noise propagation, resulting from the passage of the car or railway fleet by bridge objects. Many author's publications concerned the effectiveness of acoustic screens with filling panels made of acrylic or mineral glass. Another trend of analysis is the possibility of implementing toughened and glued glass in bridge constructions. The used of glass, which has the desired technical and strength parameters in bridges and as a filling of balustrades of bridge structures.

Some previous publications have been devoted to ways of reducing noise resulting from the passage of a car fleet through bridge joints, and in this area the correct selection of modular expansion joints, a description of how they affect the noise level, how they contribute to the intensification of vibro-acoustic phenomena and, in addition, how to use insulation under dilatation to reduce noise propagation.

In this area of scientific and research issues, I carried out, in 2013, author's research on highway bridges in Knurow Junction, within the A1 motorway, in the southern section. Field measurements and their comprehensive analyzes are described in publications R1 and B10.

After obtaining the PhD degree in technical sciences, ie from April 2005, other scientific and research interests focused on the leading issues of modern material technologies in transport engineering. On the canvas of scientific and research interests, co-authored books were published devoted to innovative technical solutions in road, bridge and railway construction.

Technological advancement in bridge construction is a proof of development in a given country, which is evidenced by the expansive development of bridge structures in China. A co-authored publication entitled "Chinese giants bridge structures" presented selected, architecturally and constructional interesting examples of bridge structures in China. It also contains statistics on how many Chinese bridge constructions have record spans of main spans on the scale of objects from around the world. The publication gives information on the number of structures built in the last decade and these are impressive data. The study has been enriched with photos, visualizations, construction drawings, in a rich color and graphic layout. The following chapters of the publication show constructions of various types that stand out in their class. It is difficult to describe all new completed buildings being in progress or in the phase of future investments, as there are thousands of them in China. However, the selection made for the purposes of the publication is sufficient to show the outstanding pace of Chinese bridges and the richness and diversity of the systems used, materials used, the way of shaping the aesthetic form, etc. It is also a good educational material, which generally introduces the types of bridges, describes their components, and differentiates the types of construction solutions adopted.

An important technical parameter is the durability of the material. Therefore, an important area of my research and scientific interest is the durability of construction materials used in bridge constructions. Material engineering is looking for engineering plastics with the desired strength parameters, but also non-corrosive, being an alternative to traditional materials. Both CFRP and GFRP polymer composites as well as cement composites with dispersed fibers are a new opening towards applications in construction, including bridge construction. Authors' publications on cementations composites, namely concrete with steel fibers with the presence of nano and microsilica are embedded in this thematic trend.

Innovative composite materials, which are an expression of the progress of material and bridge engineering, are related to the aesthetic dimension of bridge structures. The visual form of bridge structures using modern glass, polymer and cement composites is also a research trend and has been reflected in the author's articles.

After obtaining the degree of technical sciences, I published: 6 monographs, books and scripts; 10 chapters contained in books and monographs; 3 article published in the journal from list A; 35 articles published in English and Polish in journals classified as list B of the Ministry of Science and High Education; 17 conference papers printed in the materials of foreign and domestic conferences; 16 other articles.

Nowadays, the problems of polymer and cement composites and the comprehensive recognition of their suitability in bridge engineering are, in my opinion, an innovative, progressive trend of scientific research. In a perspective, two leading, original scientific research topics (doctor's canvas and GFRP use) will be combined. Comprehensive analysis will be based on determining how the GFRP composite panel used in the modernized bridge construction contributes to the reduction of construction vibrations, reduction of noise propagation, etc.

The research activity used in engineering practice is reflected in the completed proprietary expertise, which arose on the occasion of being appointed as a court expert, in the course of cases conducted by judicial authorities at various levels in Opole, Katowice, Gliwice, Wroclaw, Zielona Gora and Kwidzyn. Technical studies (in the number of 17 works) concerned the causes of design and implementation irregularities in road and bridge projects, were supported by in-situ research and a comprehensive analysis of technological conditions of the investment. The progressive topic taken in the sphere of co-partner activities with the accredited Lab and the Chemical Department of the Rzeszow University of Technology is a method of modifying the asphalt surface by using the Asfix Alpha additive. This additive, as an asphalt surface modifier, for use in the wear layer of the road structure and in the pavement on bridge structures, has been positively evaluated by the Research Institute of Roads and Bridges and will be notified to the Patent Office in 2018. Adhesion of asphalt to aggregate grains is a surface phenomenon and depends on the contact of both materials and their mutual affinity. Adhesive agents are able to effectively generate more favorable adhesion conditions. The results of the co-authored material tests confirmed the ability of Asfix Alpha to increase the adhesion of asphalt to aggregate. The improvement of the adhesion conditions, with the participation of the modifier, consists in reducing the interfacial tension of the asphalt / aggregate system and achieving the aggregate tangibility of the aggregate through the asphalt also in the presence of water. The addition of an Asfa Alpha adhesive to (used in tests) asphalt road 50/70 generates much better resistance to water. In comprehensive analyzes, all the obtained results of thermal stability tests were positively evaluated. The adhesion of asphalt with the addition of Asfix Alfa to various types of aggregate demonstrated in standard tests is at a very good level of 80-95%, which confirms the effectiveness of its impact.

A different theme carried out jointly with Labor Aquila is durability, including frost resistance of cement concrete pavement, made in rolling concrete technology. The cooperation so far has been based on the study of concrete pavements made on pilot road sections.

The frost resistance of concrete made in RCC technology (Rolled Compacted Concrete) is not yet fully recognized in domestic conditions. American literature presents the results confirming the good frost durability of the RCC pavement, in typical operation conditions for local roads, parking lots, parking spaces, etc. Own experiments and the Labor Aquila Research Laboratory concerned observation and testing of paved concrete on the sections made of roads, after a few winter seasons. Verified surfaces from RCC did not show signs of destruction, despite the use of winter road maintenance measures. The subject of original material technologies, the use of engineering plastics, which characterize the properties that increase durability and ease of application in bridge and road constructions, is a platform for research and development that is still under development.

5.3. Summary of research work

Generally, own research, scientific and design work is related to the possibilities of implementing alternative materials and technologies in bridge and road construction, in relation to traditional solutions. Scientific and research activities are primarily focused on polymer and cement composites. In the publication activity, I present in a comprehensive way the state of knowledge in the field of innovative technological solutions in communication engineering, in the aspect of increasing the durability of the structure and shortening the time of their implementation.