ZAŁĄCZNIK NR 4 / ATTACHMENTO NO 4

AUTOREFERAT / SYNOPSIS

specification of achievements being the subject of habilitation process
and scientific-research and didactic activities, professional and organizational

Dr inż. Lidia Buda-Ożóg

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1. PERSONAL DATA

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2. DIPLOMAS, SCIENTIFIC DEGREES

2.1 Scientific degrees

Master's degree in civil engineering

- Date of awarding: 12th June, 1996
- Unit: Faculty of Civil and Environmental Engineering
- Specialisation: Engineering structures,
- Thesis title: Research and assessment of accelerated maturation opportunities in the production process of prefabricated elements,
- Supervisor: Grzegorz Bajorek, PhD, Eng.
- Reviewer: Aleksander Starakiewicz, PhD, Eng.

Doctor's degree in technical sciences

- Date of awarding: 09th January, 2008
- Unit: Council of the Faculty of Civil and Environmental Engineering,
- Discipline: Civil Engineering,
- Thesis title: **Diagnostics of technical condition of concrete elements using dynamic methods**,
- Supervisors: Władysław Łakota, Senior PhD, Eng., PRz prof.,
  prof. Leonard Ziemiański, Senior PhD, Eng.,
- Reviewers: prof. Tadeusz Uhl, Senior PhD, Eng. (AGH),
  Szczepan Woliński, Senior PhD, Eng., PRz prof.

2.2 Professional qualifications

• Type: Unlimited design licence in civil engineering and construction
• Date of awarding: 12th November, 1997,
• Licence number: 36/97,
• Unit: Province Office in Rzeszow.

• Type: Certificate authorising structural design concerning renovation, construction and adaptation works in facilities under conservator's charge,
• Date of awarding: 26th August, 1998,
• Number of the certificate: 150,
• Unit: Provincial Conservator of Monuments.

3. EMPLOYMENT HISTORY

- 06.1996 – 10.1999 Design and Construction Services, Władysław Jagiełło, Rzeszów Al. Niepodległości, Design Assistant, since 1998 Structural Designer,
- 11.1999 – 09.2006 Rzeszów University of Technology, Faculty of Civil and Environmental Engineering, Department of Construction Research, Assistant,
- 10.2006 – 09. 2010 Rzeszów University of Technology, Faculty of Civil and Environmental Engineering, Department of Construction Mechanics, Assistant, since March 2008 Assistant Professor,
- 10. 2010 – till today Rzeszów University of Technology, Faculty of Civil and Environmental Engineering, Department of Construction, Assistant Professor.

4. ACHIEVEMENTS ACCORDIND TO ART. 16 PAR. 2 LAW OF 14.03.2003 ABOUT SCIENTIFIC DEGREES AND SCIENTIFIC TITLE AND TITLE IN THE FIELD OF ART

4.2 Scientific goal

Shaping construction objects in the aspect of increasing durability, quality, reliability and safety of buildings is possible through the implementation of new materials, technologies or new design and construction solutions. Reliability of building structures is an important design criterion, while the required level of security depends not only on the function and purpose of the facility, but also from the parameters included in the calculation. Despite numerous studies on safety and reliability, there are factors, with a certain probability, that increase the uncertainty of the parameters assumed in the calculations and as a result the structure fails. Since such failures usually have not only a material but also a human dimension, the optimisation of the structure in order to maximise its reliability should be a prime objective over the other optimisation criteria. Despite a fairly common understanding of the importance of structural safety, a reliability analysis is not a generally accepted design practice, as it is the use of random variable quantum multipliers that is believed to guarantee safety. Such an approach is contained in the current standard regulations, where the measure of reliability is the use of an appropriate set of partial coefficients modifying representative values of variables determining the state of the structure. This method, however, does not provide quantitative information on the reliability of the structure, it only allows for a bivalent assessment of the safety of the structure, i.e. the structure can be considered as either safe or unreliable. Thanks to the progress made in calculation techniques, the design of the structure taking into account the quantitative evaluation of the reliability of the structure may become a conscious design process of engineers. Improvement of calculation algorithms, or popularization of alternative methods of calculation and probabilistic analyses, is therefore a necessity in order to enhance the effectiveness of the designing process and implementation of reliable building structures.

Currently, the Finite Element Method is the most popular method of designing various types of structures, including reinforced concrete structures. The results obtained from numerical calculations, however, do not give a comprehensive answer to the question how to shape reinforcement most effectively in the areas with strong discontinuities. The ST model may be helpful in this case, but here too the standard recommendations and literature do not provide rules that allow for the unambiguous determination of the shape and direction of the members in the model. The selection of the shape of the ST model and its optimization are usually carried out without assessing the reliability of the obtained model. The widespread use of such an approach to the selection of ST models has inspired me to look for an optimal solution that allows for using a rational choice of shape/geometry of the model in accordance with the principle of maximum reliability. The main aim of my work was to broaden the knowledge of theoretical and experimental issues in the field of shaping reinforcement in areas with strong discontinuities with the use of ST models that are optimal as their reliability is concerned. I also formulated the following specific objectives, resulting from the review of the knowledge contained in the paper, concerning:

- selection of the reliability estimation method, i.e. analysing the reliability structure of a complex system and using simulation techniques and stochastic models to estimate the response probability density function,
- estimation of the minimum number of intervals in the method of reduction of variance required to obtain a constant form of the response density function of the system

- estimation of the reliability of ST models of deep beams and the support zone of bent beams, adopted according to various criteria,
- comparative analysis of reliability indicators estimated by various methods,
- evaluation of the sensitivity of the reliability index to changes in probabilistic characteristics of random variables,
- the use of experimental studies to validate numerical models of reinforced concrete beams operating in a complex state of stress,
- evaluation of the load-bearing capacity, deformability and reliability of beams subjected to bending and torsional moment, designed using the ST method, and indicating the model with the most advantageous reliability structure.

This work complements the area of research and analysis concerning the selection of the optimal shape of the ST model, taking into account the criterion of maximum reliability. The original element of the work is the combination of two areas of structure analysis, i.e. the use of ST models in the design of reinforced concrete structures and reliability.

4.2 Selected elements of the monograph

Research problems concerning the optimal shape of the ST model, taking into account the criterion of maximum reliability, which I presented in detail in my habilitation thesis entitled "Reliability of Reinforced Concrete Structures Designed by the Strut and Tie Method", published by the Rzeszów University of Technology Publishing House in 2019, they are largely author's and innovative material, not yet published. The most important issues from the monograph are briefly described below.

4.2.1 Load-bearing capacity of elements for ST models according to different criteria

The choice of the ST model depending on the considered issue can be made by using the truss analogy, the load path, based on knowledge of stress trajectory and methods of topological optimisation. In chapter 4 of the monograph, I compared the load-bearing capacity and deformation of selected reinforced concrete elements designed with the use of ST models, shaped according to different criteria. I presented a selected group of experimental research and numerical simulations carried out for short cantilever, support zones of beams, deep beams or various types of nodes. I compared the load-bearing capacity, deformability and cracking pattern of a deep beam with a hole with reinforcement shaped on the basis of the truss analogy and the load path. Using another example of a reinforced concrete deep beam, I compared the standard recommendations for dimensioning ST models in ACI 318, EC 2, FIB 2010 and DIN 1045-1. Another problem that occurs during the analysis of structures designed using the ST method is the very different values of correction factors, often correlated with the angle of inclination of the compressed struts. The paper presents selected experimental studies and simulations carried out for the deep beam in order to determine the effect of the angle of inclination of compressed struts on acceptable compressive stresses in concrete struts and nodes. Chapter 4 of the monograph also contains a review of the results of tests of short cantilevers shaped on the basis of ST models. The compressive stresses in the analysed ST models were limited to different values according to the recommendations of Eurocode, Canadian, American, Australian and New Zealand standards. Another area of application of ST models are nodes and corners in reinforced concrete structural elements. In this paper, I presented the results of research and analyses concerning the load-bearing capacity and deformation of these elements, with reinforcement shaped on the basis of the conventional ST method and with the use of non-linear ST models.

The studies presented on the basis of the literature review confirm the complex nature of the phenomenon and the possibility of obtaining various results depending on the adopted optimization criterion in the ST model. As shown in each of the presented examples, the bearing capacity of elements designed by the ST method is different depending on the model or standard recommendations, but it is always estimated in a safe way that meets the load capacity conditions. While reviewing the publications, I did not find a study in which the ST method would be used to dimension and shape the reinforcement in spatial bent and torsional beam elements. The lack of such studies and results became an inspiration to take up this topic and carry out research, the results of which I presented in this paper.

4.2.2 Methods for estimating the reliability of structures

I used various techniques to assess the reliability of models and structural elements designed using the ST method, i.e.:

- analysing the reliability structure of a complex system such as the ST model,
- and using simulation techniques and stochastic models to estimate the response probability density function.

The reliability structure of complex technical objects and the reliability of such objects can be analysed by various methods. In chapter 5 of the monograph, I discussed selected methods, allowing estimation of the reliability of certain classes of non-renewable systems which can be implemented in the analysis of reliability of limit states of load-bearing capacity of building elements and structures. I presented non-renewable systems with serial and parallel structures and non-renewable systems with complex structures. I discussed the influence of correlation on the load-bearing capacity and reliability of systems. I used the method of estimating the reliability of serial systems with correlated elements to analyse the reliability of selected structural elements presented in the operation of ST models.

The classical reliability assessment methods use defined limit state functions, safety margin, which are open functions of random variables. Such a functional dependence in practical implementations occurs only for very simple examples and is practically impossible to apply in non-linear reinforced concrete structures with implicit border state functions. Therefore, more and more often in the case of realistic structures and implicit border state functions, their reliability is calculated using a numerical procedure, most often using the finite element method. In all simulation methods, it is possible to distinguish several common, main steps, such as: formulation of stochastic models of the studied processes, numerical modelling of random variables with a given probability distribution, called the generation of random samples, and solving a statistical problem in the field of the estimation theory. The use of the classic Monte Carlo method in combination with the finite element method is generally ineffective as it requires a large number of implementations in order to obtain reliable results. Therefore, in many cases the Monte Carlo method is used together with other methods to shorten the calculation process or as an alternative method to compare the results obtained by other methods. In this study, the reduction of random variables population size was carried out by Latin Hypercube Sampling (LHS) method. On the basis of histograms of responses obtained for a number of random variables and a specific population size, I made an estimation of the implicit function of probability of response density, which I used for linear or square approximation of the failure area using the FORM and SORM (FORM - First Order Reliability Method, SORM - Second Order Reliability Method) methods. I determined the Cornell reliability index directly from the response histograms obtained from the simulation.

4.2.3 Examples of estimating the reliability of structures designed using the STM

In chapter 6 of this monograph, I presented an estimation of reliability of selected elements designed with the ST method. One of the elements was a reinforced concrete beam, in which the support zone was shaped with the use of various ST models. I assumed that random variables of the material from which the beam was designed and the load are characterized by a normal distribution, described by the first two statistical moments, i.e. the average value and standard deviation. I analysed three ST models of support zone D. I designed Model 1 using a free-of-charge algorithm to optimise the shape of the replacement truss, adapted to work in the Matlab environment. Model 2 was an intuitive model, statically measurable, with vertical tension rods representing the reinforcement of the stirrups in the support zone. The model 3, on the other hand, consisted of a statically non-designated flat truss. I analysed two cases, i.e. no correlation between the elements of the model and full correlation of elements from the same material. On the basis of the analyses, I noticed that the evaluation of the reliability of structures designed using the classic method and ST models leads to very different results. In the traditional calculation of an element, the reliability of a structure is equal to the reliability defined in the critical section, which may result in an overestimation of the reliability index. Structures designed using truss models have a strictly defined reliability structure, which allows for a more reliable estimation of their reliability. The analysed ST model of the support zone of the bent beam had different reliability and different masses of reinforcement steel required for shear. The most advantageous reliability structure was characterized by model 3 with a lower reinforcement mass than required for model 2.

In the monograph, I also presented an estimation of the reliability of a deep beam with a hole, with different topology of the adopted ST models. I subjected six deep beams of the same dimensions and external load, but with reinforcement shaped according to different ST models, proposed in the publications from 2002 to 2017. The reliability analysis was preceded by the execution of numerical models of the deep beams in question. The deep beams were characterized not only by a different crack pattern, associated with the adopted ST model, but also by a different value of displacement of selected points of the deep beam and the value of limit load. In the next step, I evaluated the reliability of the analysed elements, using fully probabilistic level III methods. In the stochastic model, I assumed that the input values are described by mean, standard deviation and type of distribution. As suggested in the literature I assumed the coefficient of variation and type of distribution for the input variables of concrete and steel. I also took into account the correlation structure between random variables in concrete, defining the initial correlation matrix. Using the Latin Hypercube Sampling method (LHS) for the declared number of intervals, I chose representative parameters of random variables. The selection of the optimal number of samples for the LHS variance reduction method was preceded by the analysis of the influence of the number of input variables on the statistical response of the structure. The structural response sets obtained from the simulation were statistically evaluated and led to the following: the estimated mean value, variance, coefficient and curtosis and, on the basis of an empirical histogram, the response - an approximate form of the probability density function. I also carried out a sensitivity analysis to determine the significance of individual random variables for the response of the system. On the basis of the results of the statistical analysis, I estimated the reliability of the deep beams, and I determined two reliability measures, i.e. the Cornell reliability index and the FORM index, as well as the corresponding probability of failure. On the basis of the analyses, I noticed that the average bearing capacity of the deep beams ranged from 55.3 kN to 64.6 kN and it was not closely related to the amount of reinforcing steel, but to its optimal distribution. In the case of the ST model deep beam, based on force paths, the estimated Cornell's reliability index did not meet the requirements of design class RC2 and 50 years of use. In other analysed cases, the Cornell reliability index ranges from 4.69 to 5.14 and the index estimated by FORM method from 4.40 to 7.71. Taking into account the efficiency indexes defined as the ratio of Cornell's reliability index to the weight of reinforcement steel, the most advantageous results were obtained for the deep beam of ST model obtained as a result of topological optimization by GSM (Ground Structure Method).

In chapter 6, I also presented an estimate of the reliability of multi-span deep beams. I analysed three ST models. The first model was the simplest bar structure, statically determinable, with only horizontal tension bars. The second model was also a statically determinable bar structure, but with horizontal and vertical tension bars. The third model was a statically unidentifiable structure with horizontal and vertical tension bars. In my work, I compared the probability of failure and reliability index for the analysed deep beams with two methods. The first method took into account the reliability structure of the elements, in the second one, I estimated the reliability with simulation methods, building a stochastic model, i.e. taking into account information on random variable distributions. The assessment of the reliability of deep beams with differently shaped reinforcement confirmed that designing with the use of ST models, regardless of the adopted model, provides the safe load-bearing capacity of elements. However, this is a method that requires the designer to be able to shape the reinforcement in order to limit cracks and reduce expected deformations. Analysing the reliability of deep beams, taking into account their reliability structure, we get a safer estimation than the one obtained with the use of the Monte Carlo method with the use of variance reduction techniques. Irrespective of the method adopted, I did not notice any significant differences in the obtained reliability indices of individual deep beams. A beam with reinforcement shaped on the basis of the third model is slightly more reliable in comparison with the other two, as well as less cracked and deformed. The use of structural reinforcement recommended in the standard has a positive effect not only on the reduction of cracks and deflections in deep beams, but also on a significant increase in their safety. The examples presented in this paper show that ST models that are statically indistinguishable internally, are characterized by a more advantageous reliability structure than statically determinable models.

4.2.4 Own testing of reinforced concrete beams designed with the STM

In chapter 7 of the monograph, I presented my own research of twisted and bent reinforced concrete beams with reinforcement shaped on the basis of three different ST models. The subject of analysis was a cantilever reinforced concrete beam with real dimensions shown in the figure 1.

a) b)

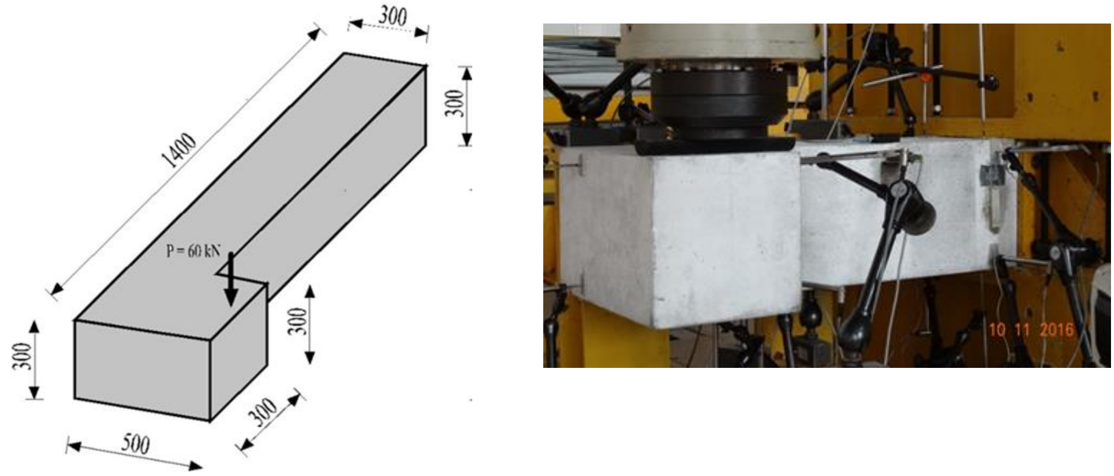


Fig. 1 Analysed cantilever beam, a) geometry and reinforcement of tested beams, b) the view of the test stand

In chapter 7 of the monograph, I presented my own research of twisted and bent reinforced concrete beams with reinforcement shaped on the basis of three different ST models. The subject of analysis was a cantilever reinforced concrete beam with real dimensions. I analysed three truss models. Model 1 was a 3D truss with a Leonhardt truss shape, in which the compressed concrete struts, separated by diagonal lines, are inclined at an angle of 45° to the axis of the bar on each side, both vertical and horizontal. The vertical bars of the truss are stretched reinforcement in the form of stirrups. The top and bottom chords of the truss are reinforced tension and compression concrete chords. In model 2 of the 3D truss, the compressed concrete struts are at an angle of 37° to the bar axis, while in model 3 they are at an angle of 27°. On the basis of the obtained values of forces in the truss bars, I selected the longitudinal and transverse tension reinforcement, checked the condition of not exceeding the permissible stresses in the compressed elements and the conditions of anchoring the reinforcement in the nodes. Then I carried out experimental research, which included three series of reinforced concrete beams with different shapes of reinforcement based on ST models. Due to the statistical representativeness and reliability of the obtained results, each series contained four beams of the same parameters, i.e. concrete class and reinforcement. The results obtained from the measurements were statistically evaluated. On the basis of the experiment, I noticed that the average breaking load, depending on the model, ranged from 121 kN for model 1 to 97 kN for model 3. Beams with reinforcement shaped on the basis of different ST models are also characterized by different deflection and angle of rotation of the lateral plane. There was also a different measure of scattering of the results obtained, in the case of breaking load and deflection, a relation between the value of standard deviation and the adopted ST model was visible. In the next step, I made a numerical analysis of beams in ATENA 3D - Studio. For non-linear analysis of reinforced concrete beams, I used concrete models describing the dependence $\sigma - \varepsilon$ in the complex state of stress with material parameters modified in accordance with the results of strength tests of the concrete used. I modelled the reinforcement discreetly using the reinforcement model built into the ATENA program to ensure adhesion between concrete and reinforcement. Initially, the beams to be tested were supposed to be fully fixed, but during the tests, due to inaccurate beam design and surface irregularities in the adhesion of the planes, small displacements were observed at the junction between the beams and the steel members of the fixture. This was taken into account by using a conventional material in the numerical model, the "interface", the behaviour of which, under load, was supposed to reflect the minimal inaccuracies in the beam execution and the occurrence of displacements at the beam - steel elements junction. The properties of the "interface" material are based on the Mohr-Coulomb criterion which, in the presented numerical model, I selected on the basis of the digital correlation of the displacement results in the three analysed directions, so that the numerical model's compliance with the results of experimental tests was as full as possible. I used the constructed and validated numerical models to estimate the reliability of the analysed beams. I estimated the reliability of beams in two cases. In the first case I assumed material parameters in accordance with the initial assumptions, i.e. concrete C35/45, because for this type of concrete the ST method was used. In the second case, I estimated the reliability of beams assuming the strength of concrete parameters on the basis of the results of experimental tests. The reliability of beams was assessed using probabilistic methods - FORM and SORM and fully probabilistic Monte Carlo with the use of variance reduction techniques by Latin hypercube. The FORM and SORM methods use a full probabilistic description of random variables, i.e. the mean, standard deviation and information about the probability density function, which I determined on the basis of numerical simulations. As suggested in the literature, I assumed the standard deviation, type of distribution and correlation dependencies for the input variables of concrete and steel. Taking into account the time of calculation and the accuracy of the obtained results, I optimized the number of samples in the LHS method. The optimization criterion was the approximate stabilization of the Cornell reliability index and the reliability index determined by the FORM method. In the case of the analysed beams, not only the maximum load but also the vertical displacements of the selected point and the angle of rotation of the side plane of the beam were statistically evaluated. As a result of the statistical evaluation, the reliability of the beams was evaluated, taking into account the effects of actions assumed at the ST model adoption stage. The presented results of the reliability analysis confirmed the safe estimation of load capacity in ST method for B1 and B2 series of beams with the angle of inclination of struts 45^{o} and 37^{o} respectively. However, for the B3 beam and pre-approved concrete class C35/45, the Cornell reliability index is slightly lower than that recommended in the standard (PN-EN 1990, 2004) for RC2 construction class and 50 years of use. The highest reliability in terms of load-bearing capacity, deflection and the angle of rotation of the lateral plane is characteristic of the B1 series of beams. Although the measured deflection of the selected point and the angle of rotation of the lateral plane are slightly higher than that of the other two series of beams under analysis, the obtained results have the lowest coefficient of dispersion.

I also assessed the reliability of the complex structure of the adopted ST models. The elements designed with the ST method are characterized by a defined reliability structure, allowing for estimation of their reliability, as well as determining the impact of individual components on the reliability of the whole element. The models of beams presented in the work have a serial reliability structure. Due to the method of execution of this type of elements (the same concrete and reinforcement) in the conducted analyses, the full correlation of upper belt elements, upper reinforcement, full correlation of lower belt elements, compressed concrete, full correlation of elements representing individual stirrups and concrete in struts between stirrups was assumed. The reliability of the adopted structures was estimated in the Strurel package (Comrel, Costrel and Sysrel) enabling the user to define the limit state function in the notation of the symbolic processor. If the vector is not a Gaussian vector, the user can choose between Rosenblatt, Nataf or Hermite transformations. In the case of normal and logarithmically normal variables, the model dependency structure can be given directly by means of correlation coefficients obtained from the covariance matrix, while in the mixed model, correlation coefficients in the input matrix should be given. In the reliability estimation, I have assumed minimum load-bearing capacity cross-sections in the ST model and higher in accordance with the actual state. The reliability index and probability of destroying the whole system was estimated using two methods, i.e. FORM and SORM. The estimated reliability of the systems, taking into account their structure, is similar to the reliability obtained by simulation methods based on the assumed approximate form of the probability density function. Reliability assessment based on the reliability structure of the system is a simpler and less time-consuming approach than simulation methods. The analysis based on the reliability structure of the system allows not only for a faster reliability assessment, but also for the determination of the impact of changes in positional parameters and dispersion of random variables on the system reliability differentiation, i.e. the evaluation of the system's sensitivity to changes in the quality of materials or constant or variable load. An example of such analyses was presented in my work analysing different classes of concrete – fig. 2 and different load variation coefficients.

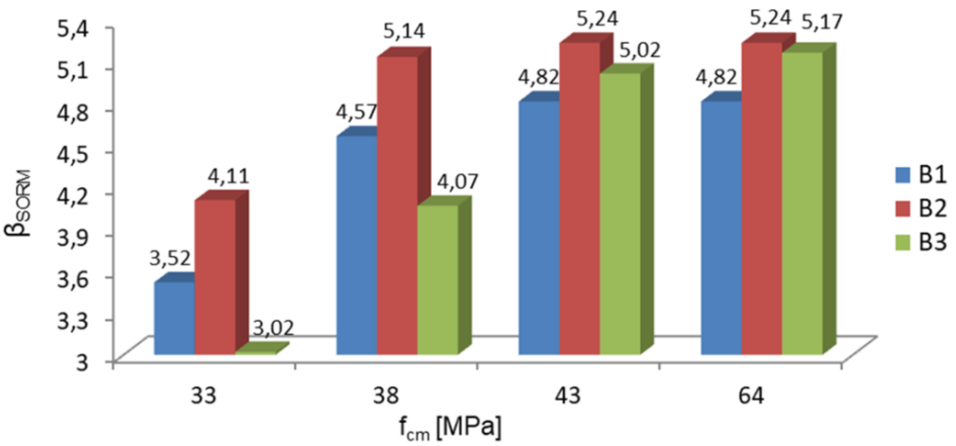


Fig. 2 The impact of concrete strength on the reliability index of complex beam reliability systems

Knowledge of the reliability characteristics of the system components and their influence on the reliability of the whole structure also allows for a conscious increase of the safety of the analysed structure by increasing the reliability of the weakest elements in the structure. Selected simulations aimed at increasing the reliability of the system by increasing the reliability of the weakest link were presented in this work.

4.3 Summary - the main achievements

As it has been shown in this paper, the choice of the ST model may vary depending on the considered issue. This diversity is not only due to the choice of a model design method, i.e. using the analogy of the equivalent truss, force streams, stress trajectories or topological optimisation methods, but also to the shape and direction of the individual elements in the model within the same method. This variety of adopted models results in the possibility of obtaining different ultimate load-bearing capacity, deformability or crack image of the designed elements. On the basis of the analyses and examples presented in the paper, it has been shown that the adoption of different ST models determines the different reliability of the analysed systems and elements. The current state of advancement of reliability theory and continuous improvement of reliability estimation calculation methods motivates engineers to use optimal methods of shaping engineering structures in the design process and ensuring their maximum safety rather than to choose commonly used semi-probabilistic methods, based on partial safety factors.

On the basis of the conducted analyses, it was noted that an important issue in the reliability assessment is the adoption of a calculation model that is closest to reality. When building a model, the designer has to decide which design parameters should be considered as deterministic and which as random variables. What type of distribution and description of distribution parameters are the most suitable for the accepted random variables. Additional information on the dependence of variables should also be taken into account by assuming an appropriate value of the correlation coefficient. Improper assumptions may lead to significant differences in the estimation of the reliability of a structure.

Reliability assessment of structures designed using the classical method and with the use of ST models leads to differentiated results. Structures designed with the use of ST models have a strictly defined reliability structure, which allows for a more accurate estimation of their reliability. The same structures designed on the basis of different ST models are characterized not only by different load-bearing capacity, deformability, different weight of reinforcement, but also by different reliability. This means that due to the need to ensure the reliability of a structure, the optimization of ST models should be a multi-criteria issue, so that the obtained models are characterized by optimal rigidity and maximum reliability.

The use of simulation methods allows for approximation of implicit response functions for complex in description and non-linear reinforced concrete structures. While the increase in computation capabilities of computers is one of the main reasons for the spread of the stochastic analysis, in the case of reinforced concrete elements, the application of the classic Monte Carlo method in combination with the finite element method is still ineffective. The application of the Latin hypercube variance reduction method to the generation of random samples in simulation methods of estimation of statistical moments of response functions allows for improvement of the estimation efficiency.

Reliability estimation methods using information about the reliability structure of the model are an excellent alternative to labour-intensive simulation methods. They allow it not only to estimate the reliability of the structure, but also to determine the impact of individual components on the reliability of the whole element. Awareness of the reliability of individual components and their impact on the reliability of the entire system enables its optimization so that the adopted model is characterized by the lowest probability of failure. Fulfilment of the condition of the highest reliability of the analysed structure can be achieved by increasing the reliability of the weakest link in the system. The methods of reliability estimation using information about the model structure can be implemented in a simple way to optimize the reliability of reinforced concrete structures designed on the basis of ST models, as shown in the presented analyses.

To sum up, it should be stated that the knowledge of the random nature of variable states, including the strength of materials and loads used, on the designed structure and the estimated probability of failure, allows for a better understanding of the behaviour of the tested structural system than the deterministic analysis, using even the most complex finite element model. The application of probabilistic methods presented in the monograph allows for the selection of the most advantageous one with regard to the reliability of the ST model, and the presented examples and methods of reliability estimation may serve as an indication in the process of ST model optimization.

5. OTHER RESARCH ACHIEVEMENTS BEING EVIDENCE OF HABILITANT'S ACTIVITY

5.2 Scientific and research achievements before obtaining the Doctor's degree

Before I obtained my doctorate, I was interested in the analysis and measurement of signal in the field of frequency. My first research work conducted under the supervision of Dr. Władysław Łakota and presented in publications [1 i 2 – attachment no 5, point II E.2] concerned methods of measurement and analysis of signals in relation to vibroacoustic phenomena. The next stage of my scientific interest was the analysis of changes in frequency characteristics obtained as a result of impulse excitation, caused by changes in stiffness of structures. The subject of the research was, among others, a bolted connection between the column and the rafter. The research presented in the publication [3 - attachment no 5, point II E.2], consisted in impulse forcing of the tested connection with simultaneous measurement of the driving force and the connection response to the given forcing. The determined frequency characteristics allowed for determining the relationship between the forces occurring in the connection bolts and changes in resonance frequencies.

In the following years I focused my interest in the use of modal analysis on the elements made of concrete. The result of my research and analysis was a doctoral thesis in which I proposed to diagnose the technical condition of concrete elements on the basis of changes in modal parameters. The aim of the research collected and presented in my PhD thesis and in the publications [4, 5, 6, 7 i 8 - attachment no 5, point II E.2 and 10 - attachment no 5, point II A.2] was to determine the relationship between the degree of damage to concrete elements and changes in modal parameters and to detect the emergency states of reinforced concrete beams on the basis of the analysis of resonance vibrations. The diagnostic procedure proposed in the conducted tests was based on the dynamic analysis of the structure's response obtained in the form of frequency characteristics before damage (reference state) and after damage (for individual damage stages). The main part of the work are laboratory tests of concrete and reinforced concrete beams reinforced with CFRP carbon fibre tapes. On the basis of the obtained results of tested beams of different dimensions and different distances between the support points, an attempt was made to link the damage caused by bending, shearing, delamination of fibres from the concrete surface and cutting with changes in modal parameters. The obtained experimental results were also used to compare the physical and numerical models of reinforced concrete beams, as well as the use of artificial neural networks in the evaluation of the condition of beams.

Before obtaining the PhD degree, I was the author and co-author of nine scientific publications in the journal included in part B of the list of the Ministry of Science and Higher Education presented in Appendix 4 and 7 reviewed scientific papers included in conference materials. I presented the results of my research and analyses at five international and five national conferences.

5.2 Scientific and research achievements after obtaining the Doctor's degree

After obtaining a doctorate, my scientific and research interests included issues which can be divided into six thematic groups.

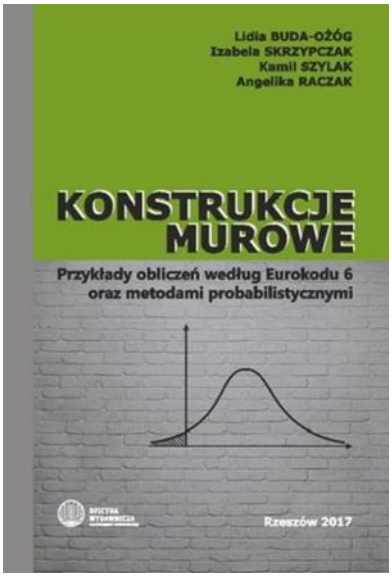
5.2.1 Assessment of the technical condition of reinforced concrete beams on the basis of changes in dynamic characteristics

After completing my PhD thesis, I continued my research related to the issue of assessing the technical condition of concrete elements on the basis of changes in modal parameters. In the publication [1, 2 - attachment no 5, point II E.1], which is a continuation of the research described in my doctoral thesis, an attempt was made to link the determined modal parameters with the observed cracks resulting from bending or shearing. Taking into account the correlation between percentage changes of selected resonance frequencies and the observed cracking, the damage was divided into four stages - related to the phases of reinforced concrete beam operation. On the basis of the conducted research, it was noticed that percentage changes of selected frequencies depend not only on the degree of cracking, but also on the nature of the damage and initial stiffness of the investigated beams. At the confidence level of 95%, on the basis of the analysis of frequency changes in all investigated reinforced concrete beams, it was possible to detect the appearance of the first cracking and the state defined as damage identified with the third phase of reinforced concrete beam operation. The detection of indirect damage conditions was burdened with a major error. The observed changes in frequency characteristics of reinforced concrete beams of different character and degree of damage were also compared with the changes in stocky concrete beams. The publication [5 - attachment no 5, point II E.1] presents an evaluation of the influence of concrete class and reinforcement degree on modal parameters changes. Three reinforced concrete beams of different reinforcement degree and different compression strength of concrete were analysed. On the basis of the research results, a slight effect of the reinforcement degree on the change in the natural frequency of the analysed beams was observed. Since experimental research on a larger population of elements is costly and labour-consuming, the publication [3 attachment no 5, point II E.1] presents the results of numerical simulations of the gradual loading and unloading of reinforced concrete beams and the determination of dynamic parameters. The numerical model of beams was built in the three-dimensional stress state in the ADINA program, and then the results of the simulation were compared with the results of experimental research. The tests presented in the above publications, unlike other tests aimed at determining the relationship between damage to an element and changes in modal parameters, were carried out not on one example element but on series of seemingly identical beams. This allowed for statistical analysis of the results obtained in order to establish a function describing the degree of damage to beams depending on changes in modal parameters.

Subsequent research work was aimed at taking into account the impact of both damage and external load on the changes of modal parameters. In the publication [4 - attachment no 5, point II E.1] on the basis of the results of experimental research, an attempt was made to link the effect of load and scratching resulting from bending with changes in modal parameters. It was observed that percentage changes in selected frequencies depend not only on the degree of cracking and initial stiffness of the investigated beams, but also on external factors such as load or additional stiffness. Summarizing the presented studies and analyses, it was noticed that as a result of modal studies conducted every certain period of use or in a continuous manner, with the use of the sensitivity analysis of frequency changes, it is possible to diagnose elements or structures. It must be remembered, however, that modal tests should be carried out under identical conditions or the influence of different types of operating conditions on the parameters of the modal model of the tested object should be determined and separated beforehand.

My scientific contribution to the presented research and analyses is practically 100 per cent. The co-authors of the publications [4 i 5 - attachment no 5, point II E.1] were Master's degree candidates under my supervision, and the presented results came from the research carried out as part of their Master's theses. The co-author of the publication [1 - attachment no 5, point. II E.1] was Władysław Łakota, who died in 2006, i.e. 2 years before the article was completed. However, due to his valuable guidelines and goals set for my research, I decided that I should emphasize Władysław Łakota's contribution to this publication as a co-author.

5.2.2 Reliability of masonry structures



Masonry structures are another area of my scientific interest along with reinforced concrete structures. In my analyses, I am particularly interested in the reliability of masonry structures, which, despite the considerable uncertainty of the obtained results, have not been the subject of extensive research in the past. Differentiation of partial coefficients proposed in PN-EN-1996-1-1-1 and their significant values served as an inspiration for a probabilistic approach to masonry structures. In the monograph [1 - attachment no 5, point II E.1]], the basic procedures in accordance with the currently valid standards for dimensioning and checking the load capacity of unreinforced and reinforced masonry structures subjected to compression, shear and bending forces are presented. The theoretical bases and examples of checking the load capacity of the most common reinforced and unreinforced masonry structures presented in the paper were extended by examples of estimating the load capacity of these structures using probabilistic methods. The paper also includes a chapter on the basics of structural design and theoretical basics of designing masonry structures using the probabilistic method. I participated in the work on all chapters of this monograph. My contribution to this handbook was 30 per cent and concerned the elaboration of chapters containing the theoretical basis for checking the load capacity and verification of the calculation examples presented in the paper. The publication [4 - attachment no 5, point. II A.1] is a continuation of the problem of evaluation of the reliability of masonry structures. The reliability analysis presented in the publication concerned a reinforced masonry lintel. Various analytical models of the lintel, for which a stochastic model was built, were analysed and on the basis of the FORM and Monte Carlo simulation methods for the limit state function the reliability index was estimated due to bending and shear. It was noted that in the case of shear strength of a masonry wall, defined as a random variable with logarithmically normal distribution and coefficient of variation according to the recommendations proposed in the literature, amounting to 19 per cent, the estimated reliability index was lower than that recommended for RC2 structures and the reference period of fifty years. The aim of the publication was to draw attention to the differentiation of the obtained reliability index of a masonry lintel depending on the nature of the description of random variables and the method of reliability estimation. My contribution to this work consisted of the theoretical part of the publication, in particular the literature review and verification of the model to determine reliability; my share came to 33 %.

5.2.3 Use of ST models

The load-bearing capacity and deformability of reinforced concrete structures designed using the ST method was the subject of several publications preceding my thesis. In my analyses, I investigated structures with reinforcement shaped on the basis of ST models, working in a flat state of stress and spatial elements. In the publication [15 attachment no 5, point II E.1], I presented the results of numerical simulations of a deep beam with reinforcement based on the ST model. I analysed two cases, the first one, when the tension reinforcement was concentrated in the area of the placed T-bars, and in the second one, the reinforcement was evenly distributed over the assumed area. The aim of the research was to assess the influence of reinforcement distribution on the deep beam cracking, deformation and stress values in steel and concrete. In the publication [13 - attachment no 5, point.. II E.1], I analysed the quantity and distribution of orthogonal reinforcement required due to torsion and shear in two reinforced concrete elements, i.e. for a beam curved in the plan and loaded evenly and a cantilever beam loaded eccentrically with concentrated force. I compared the obtained reinforcement on the basis of ST models with the reinforcement obtained from the dependencies proposed in PN-EN-1992-1-1 in points 6.2 and 6.3. I noticed significant differences in the obtained reinforcement surface and the method of its distribution depending on the adopted method. The problem of evaluating the torsional load capacity of the cantilever beam was continued in the publication [18 - attachment no 5, point II E.1]. The aim of the research (numerical simulations) was an analysis of the influence of reinforcement shaping on the basis of three ST models on limit load capacity, residual load capacity, torsional stiffness and cracking of 3D-beams. In the articles [3 - attachment no 5, point II A.1 and 22 - attachment no 5, point II E.1], I presented the results of experimental research conducted on real reinforced concrete beams subjected to torsion, shear and bending. I shaped the reinforcement in the beams on the basis of three different models. The aim of the analyses presented in the publication [3- attachment no 5, point II A.1] was to compare the torsional stiffness obtained from experimental studies with the torsional stiffness calculated from the relationships proposed by Lampert and Thurliman and Hsu .The aim of the analyses presented in the publication [22 - attachment no 5, point II E.1] was, on the other hand, to assess the conformity of the results obtained from numerical simulations of reinforced concrete beams bent, sheared and tensioned at the same time and designed with the ST method with the results of experimental tests. In the presented numerical simulations, different models of concrete were analysed. All the listed publications concerning the use of ST models [13, 15, 18, 22- attachment no 5, point.. II E.1 and 3- attachment no 5, point II A.1] are independent publications and my share in them was 100 %.

5.2.4 Load-bearing capacity, deformability and cracking of reinforced concrete elements on the basis of numerical models and experimental studies

As part of the EU project "Internship of a successful scientist", I completed a 6-month internship in a prefabrication plant Solbet in Kolbuszowa. For the needs of the prefabrication plant, I designed WIPRO type pipes with a diameter: 500 mm, 600 mm, 800 mm, 1000 mm and 1200 mm adapted to increased loads and I carried out preliminary experimental tests of the designed elements. The project involved the need of analysing the tensile strength of concrete in strongly curved bent elements. The strength of bent elements with high relative curvature is significantly different from the strength assumed for undistorted elements. The correct design of the pipes in question involved numerical simulations presented in the publications [2- attachment no 5, point II A.1 and 12 - attachment no 5, point II E.1]. In the publication [12 - attachment no 5, point II E.1] a flat model of WIPRO type pipe was analysed and my contribution to the publication consisted in making a numerical model and treating the results of experimental tests and constituted here 50 per cent. In the publication [2- attachment no 5, point II A.1] the 3D numerical model was compared with the results of experimental tests carried out on a real object. This publication was created in cooperation with Izabela Skrzypczak, PhD and Joanna Kujda, M.Sc and my contribution was 33 per cent and consisted in verifying the numerical model and treating the results of experimental tests. The inspiration for subsequent numerical simulations presented in the publication [8- attachment no 5, point II A.1 oraz 25 - attachment no 5, point II E.1] was the need to assess the load-bearing capacity of the slab system [expert opinions no 6 - attachment no 5, point II F.2]. In order to assess the stress-stain state of the slab system and then assess the effectiveness of the desinged reinforcement, numerical models of the analysed system with and without reinforcement were made. The slab in question was characterized by a complicated shape, and numerous holes in the slab zone made it impossible to properly assess the puncture resistance using classical methods. Excessive deformation of the slab in the middle strips posed another problem. In order to assess the slab load capacity in the column strips and deflection in the middle strips, and then to assess the effectiveness of the designed reinforcement, detailed numerical models of the analysed slab with and without reinforcement were made. In the analysed numerical models, non-linear concrete material models describing the dependence $\sigma - \varepsilon$ in the complex state of stress with some strength parameters obtained from the performed measurements were adopted. The reinforcement was modelled discreetly, using a linear material model of steel with reinforcement. The spatial MES models were made in ATENA 3D - Studio program. The publication [25 - attachment no 5, point II E.1] was created in cooperation with Joanna Kujda, M.Sc, and my contribution was 50 per cent, and consisted in verifying the numerical model and designing the required reinforcement. The publication [8 - attachment no 5, point II A.1] was created in a team of three people, and my contribution was 33 per cent, and similarly as before it consisted in verifying the numerical model and designing the required slab reinforcement.

5.2.5 Reliability of reinforced concrete structures

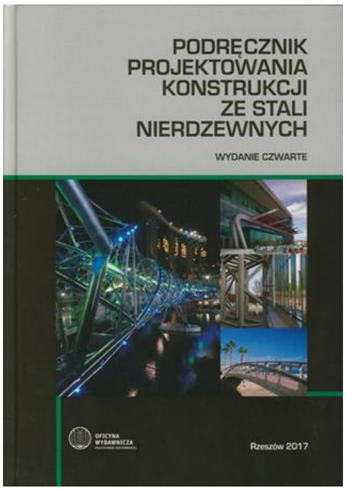
The evaluation of reliability of reinforced concrete structures and standard recommendations concerning this issue have been presented in several scientific publications of my authorship or co-authorship. The publication [20 - attachment no 5, point II E.1] is of review character and it has been shown that the target reliability index values according to various national and international standard recommendations are not consistent. In the article, an attempt was made to explain the relation between the required reliability index and the designed life expectancy and to determine the relation between the target reliability level for the given consequences of failure and the designed life expectancy. The publication was co-authored with Izabela Skrzypczak, PhD, Joanna Kujda, MSc and Janusz Kogut, PhD from Cracow University of Technology. My contribution to this publication accounted for 25 per cent and consisted in reviewing the recommendations concerning the designed period of use and the target reliability level contained in standards and documents. The aspect of designing reinforced concrete elements with assumed reliability was also presented in the publication [9 - attachment no 5, point II E.1]. In the publication, the reliability index of a reinforced concrete spheroidal compression column was estimated depending on the heterogeneity of the concrete used. Then the obtained results for the assumed reliability levels were compared with the recommendations contained in the analysed standards and documents. In the publication [5- attachment no 5, point II A.1] the analysis of reliability of reinforced concrete foundation slab is presented. The reliability index and probability of failure of the analysed element were estimated using various methods, i.e. FORM analytical method and FORM, SORM and Monte Carlo simulation methods. In order to assess the safety margin, the obtained values were compared with the limit values for the assumed reliability class and expected lifetime. The fully probabilistic approach proposed in the publication to the assessment of the foundation's safety margin in case of increased loads or changes in soil parameters can represent an alternative to other methods, e.g.

strengthening. The publications [9 - attachment no 5, point II E.1 and 5 - attachment no 5, point II A.1] were created in cooperation with Izabela Skrzypczak, PhD, and Marta Słowik, PhD, from Lublin University of Technology. My contribution to each of these publications is 33 per cent. My contribution to the work in the publication [9 - attachment no 5, point II E.1] consisted in the development of an algorithm for determining the reliability index of reinforced concrete elements, while in the publication [5- attachment no 5, point II A.1] my contribution consisted in the calculation of the reliability indexes by FORM, SORM and Monte Carlo simulation methods of the analysed foundation slab. In the publications [24, 26 - attachment no 5, point II E.1] single and multi-span reinforced concrete deep beams were subjected to reliability assessment. In the case of single-span deep beams [26 - attachment no 5, point II E.1] I used simulation methods to approximate implicit response functions, and then, on the basis of response histograms, I estimated Cornell's reliability index. The aim of the analyses was to assess the influence of the arrangement and shape of reinforcement on the reliability of the deep beams. Another method of reliability estimation was proposed in the publication [24 - attachment no 5, point II E.1], where multi-span deep beams were subjected to analyses. In this case, the reliability index was estimated by analysing the reliability structure of the system. My contribution to the publications [26 - attachment no 5, point II E.1] is 100 per cent, while the publication [24 - attachment no 5, point II E.1] was created in cooperation with Joanna Kujda, M.Sc. and is the result of her Master's thesis written under my supervision. I also presented an estimation of the reliability of a complex system on the basis of the reliability structure analysis in my own publication [6 - attachment no 5, point II E.1]. The subject of analyses was the support zone of a reinforced concrete beam shaped on the basis of various ST models. The aim of the analysis was to select the most advantageous model for shaping reinforcement in the support zone of bent beams, taking into account the reliability of the ST model. The chapter in the monograph [7 - attachment no 5, point II F.1], presented at the Construction Failures conference concerned the probabilistic assessment of the column and slab floor load-bearing capacity and its deflections. This publication was a consequence of the expert's report [6 - attachment no 5, point II F.2]. Probabilistic methods of level II were used to compare the design values of effects of interactions and bearing capacity. The use of the alternative method to the method of partial coefficients made it possible to reveal the safety margin related to simplifications adopted in the basic method. The publication was co-authored by Szczepan Woliński, PhD and Joanna Kujda, MSc. My contribution to the publication was 33 per cent and consisted in estimating reliability with probabilistic methods of level II load-bearing capacity and slab deflections.

5.2.6 Concrete quality and reliability of concrete and reinforced concrete structures

My knowledge on estimating the reliability of reinforced concrete structures was demonstrated in a series of publications [6- attachment no 5, point II A.1, 8 - attachment no 5, point II E.1 and chapter in the monograph 2 i 3 - attachment no 5, point II F.1]. in cooperation with Izabela Skrzypczak, PhD. They present the problem of the influence of the compliance criterion for the sample size proposed in PN-EN 206-1 on the quality of the material embedded in structural elements. The influence of compliance control on the reliability index of concrete structures was determined and the obtained values of the reliability index were compared with the values calculated for reinforced concrete structure elements. The analyses were performed for bent and compressed reinforced concrete elements made of concrete of different compression strength and variable standard deviation. The influence of the sample size on the evaluation of the quality of produced concrete was observed, which is particularly visible when the standard deviation of concrete is over 3.5 MPa. My contribution to these publications accounted for 50 per cent and consisted in calculating reliability indicators for the analysed reinforced concrete and concrete elements. The compressive strength criteria specified in PN-EN 206-1 assume that the compressive strength of concrete has a normal distribution, which in the case of a test with a small number of n = 3 and initial production may lead to an erroneous estimation. Therefore, in the article [19 - attachment no 5, point II E.1] co-authored with Izabela Skrzypczak, PhD, we proposed an original procedure for determining the value of the test factor in the case when the strength distribution is different from normal. My contribution to the publication amounts to 50 per cent and consisted in reviewing the literature and calculating the test factor using the classic and original method. The presented issue was continued the publication [9 - attachment no 5, point II E.1],], in which the influence of sample size 3 and 15 on the estimation of the reliability index of concrete elements was compared. This publication was created in a team of three people with Izabela Skrzypczak, PhD and Joanna Kujda, MSc. My contribution constituted 33 per cent and consisted in estimating the reliability indices of concrete elements with different standard deviation of concrete compressive strength and sample size, respectively 3 and 15. In the publications [23, 27 - attachment no 5, point II E.1], the influence of material quality on the level of reliability of a reinforced concrete bent element was determined, and the obtained values were compared with the recommended values of reliability indices for reference periods of 1 and 50 years and various reliability classes. Different values of coefficients of variation of material parameters considered as random variables, assuming that they are not correlated, and the correlation between yield strength of steel and reinforcement surface were taken into account in the calculations. As a result of the analyses it was shown that for the variability of concrete compressive strength above 8%, the reliability index for RC3 structure class and reference period of 1 year is not met. My contribution to the publications was 33 per cent and consisted in verifying the calculations and partial graphic design of the obtained results. The influence of concrete quality on the adhesion of reinforcing steel in reinforced concrete structures is presented in the publication [1- attachment no 5, point II A.1]. Different grades of concrete were analysed and the results of numerical simulations were the basis for the classification of diffuse concrete compressive strength. It was shown that the criteria for division of concrete classes proposed in the standards may lead to underestimation or overestimation of concrete class, which then influences the estimation of adhesion of reinforcing steel. The publication was created in cooperation with Izabela Skrzypczak, PhD and Tomasz Pytlowany, PhD from the State Higher Vocational School in Krosno. My contribution amounted to 33 per cent and consisted in numerical model verification and literature review. The risk related to concrete quality control is presented in the publication [11 - attachment no 5, point II E.1]. For a sample size of n = 3, an algorithm of risk estimation based on the application of the fuzzy set theory was proposed. My contribution to the publication was 25 per cent and consisted in analysing fuzzy sets for concrete quality control, defining a base of rules and the calculation of the risk indicator. The chapter in the monograph entitled: "The Present and the Future of Prefabricated Building Construction in Poland " are publications [4, 5 - attachment no 5, point II F.1]. They present the theoretical basis for statistical quality control of concrete used in the production of prefabricated elements, and on the example of prefabricated reinforced concrete pipes the costs of control tests and assessment were determined. The publication was created in cooperation with Izabela Skrzypczak, PhD and Małgorzata Lenart, PhD from Cracow University of Technology; my contribution to the publications was 33 per cent, and it consisted in reviewing the literature and estimating the costs of control tests and assessment.

5.3 Other achievements - grants, internships



My other scientific achievements include my involvement in an international grant as part of a European project to promote the latest Eurocode Guidelines for Structural Stainless Steel (PUREST - Project Promotion of New Eurocode Rules for Structural Stainless Steel). The aim of the grant was to present the recommendations contained in the handbook "Design of Stainless Steel Structures", which was prepared by Nancy Baddoo of the Steel Construction Institute under the Research Fund for Coal and Steel Project (grant 709600). Participation in the project involved translating the handbook into Polish and preparing a seminar and a webinar. I translated two chapters, i.e. 3rd and 4th.

From July 2013 to December 2013 and between December 2014 and May 2015, I participated in internships realized within the framework of the project 'Internship of a Successful Scientist', constituting support for the cooperation between science and enterprises from the Human Capital Operational Programme and co-financed by the European Union from the European Social Fund. The aim of the programme was to transfer knowledge and innovation between science and micro, small and medium-sized enterprises, as well as to strengthen cooperation between science and business and to develop innovation. My first internship took place in the plant Solbet Kolbuszowa. As part of the internship, I designed documentation of sewage pipes of variable diameters, i.e. 500, 600, 800, 1000 and 1200 mm, adapted to increased road loads. My second internship took place in the Production, Trade and Service Plant "JAR". As part of the internship I optimized the dimensions of the bent concrete pipes. Preparation of design documentation for sewage pipes along with optimization of their dimensions and reinforcement required deepening the knowledge about the tensile strength of concrete in the case of bent elements with high relative curvature, whose strength significantly differs from the strength assumed for undistorted elements.

5.4 Summary of scientific activities

Summary of publication and scientific achievements

Table1 Scientific publications in Journal Citarion Reports

By base	After obtaining the Doctor's degree		Before obtaining the Doctor's degree	
	Number	Impact Factor	Number	Impact Factor
Web of Science	7	2,833	0	0
Scopus	9	2,833	1	0

Table 2 Monographs, scientific publications in international or national journals other than those in the JCR database

Type of publication	After obtaining the Doctor's degree	Before obtaining the Doctor's degree
	Number	Number
Publications in scientific journals	27	9
Monographs	1	0
Chapters in the monograph	7	0

Table 3 Number of quotations, Hirsch index, number of points

Number of quotations / number of points	After obtaining the Doctor's degree	Before obtaining the Doctor's degree
Number of points according to the Regulation of the Ministry of Science and Higher Education calculated for all publications	206 pts	27.2 pts
Hirsch Index according to the Web of Science database	1	0
Hirsch index according to the Scopus database	2	0
Hirsch index according to the Google Scholar database	2	0
Web of Science - number of quotations	3	0
Scopus - number of quotations	7	0
Google Scholar - number of quotations	17	2

Table 4 Papers presented at international and national conferences

Type of conference	After obtaining the Doctor's degree	Before obtaining the Doctor's degree
	Number	Number
International conferences	11	5
National conferences	17	4

6. OTHER DIDACTIC, ENGINEERING AND ORGANIZATIONAL ACHIEVEMENTS

6.1 Didactic activity

I started my didactic career in 2000. For several years I have been giving lectures and design and laboratory classes at the Faculty of Civil and Environmental Engineering and Architecture at Rzeszów University of Technology. Due to the employment in three organizational units, starting from the Department of Structural Research, then the Department of Building Mechanics and currently the Department of Building Structures, the subject matter of the classes have been widely diverse (theoretical mechanics, strength of materials, information technologies, building mechanics, theory of elasticity and plasticity, computer methods, concrete structures, reinforcement of building structures, selected issues from concrete structures, masonry structures, complex concrete structures, basic design of structures). I conduct classes at the first and second cycle of studies in the field of construction at Rzeszów University of Technology. For all lectures and some design and laboratory classes I have prepared didactic materials, distributed among students on the basis of reproduced materials. A detailed list of lectures, design exercises and laboratory classes can be found in attachment no 5, point III/I. For students studying masonry structures under the Erasmus programme, I give lectures and design classes in English. In 2016 and 2017 I lectured regularly at the Lviv National University of Agriculture, Faculty of Construction and Architecture, entitled: "Environmental aspect in concrete prefabrication". I have taught twice at partner universities within the Erasmus+ programme; a detailed list of universities, along with the dates of lectures is included in attachment no 5. Since 2015, twice a year, I have been carrying out Builders Licence Preparation Course, organized by the PZITB branch in Rzeszów.

6.2 Engineering activity

My scientific and didactic career at Rzeszów University of Technology was preceded by the engineering activity, since after the second year of studies I started cooperation with the Rzeszów design office, where I completed the required training. Since the moment I have been authorised to design without restrictions in the construction and building speciality, I have been the author or co-author of more than thirty expert opinions and many construction projects. Some of the expert opinions were carried out in the team of employees of the Building Construction Department. Many of these expert opinions were of a scientific and research character and often concerned problems which, when clarified or solved, required both practical and theoretical knowledge. A significant part of the expert opinions was also carried out in cooperation with the team of experts at the PZITB branch in Rzeszów, with which I have been cooperating for several years.

My expert activity concerns two areas: the first one deals with newly designed reinforced concrete structures - mainly slab systems and tanks for liquids, while the second one concerns historic masonry structures. The problems and methods of maintenance and preservation of the structures presented in the expert opinions were, among others, the subject of a paper presented at the Construction Failures Conference, as well as an inspiration for publication [8- attachment no 5, point II A.1, 25 - attachment no 5, point II E.1 oraz 7 - attachment no 5, point II F.1]. W attachment no 5, point III M and point II F.2 I limited myself to presenting most significant works in this field, confirming my engineering activity.

I also cooperated with the Solbet Prefabrication Plant in Kolbuszowa for which I designed prefabricated lintels made of autoclaved cellular concrete, estimated the load-bearing capacity of box culverts of closed and bipartite cross-section and structural design of prefabricated WIPRO pipes of different diameters. The issue of pipe design has prompted me to learn more about the problem of determining the tensile strength of concrete in the case of bent elements with high relative curvature. These works resulted in the following publications [2- attachment no 5, point II A.1 and 12 - attachment no 5, point II E.1].

For years I have also been cooperating with the design office "BiO" Budowlane Usługi Projektowe, where I am a co-designer or verifier of various construction projects, starting from sacral buildings - the church in Przybyszówka Pustki, through multi-family residential buildings, industrial halls, commercial and service buildings, industrial buildings such as tanks for liquids, decanders in sewage treatment plants and small architectural objects. Attachment no 5, point III M includes the most important construction projects that I have made for over twenty years of my engineering practice. The projects that were distinguished during the annual competition "Construction of the Year of the Podkarpacie Region" organized in various categories are worth mentioning [attachment no 5, point III D].

6.3 Organisational activity

Throughout my work at Rzeszów University of Technology I have taken part in the work of organizational committees of four international and national conferences and I have participated in the work of scientific committees of two national conferences. A detailed list of the conferences is given in attachment no 5, point III C. I also participated in the works of the organizing committee appointed by the Dean of the Faculty of Civil and Environmental Engineering and Architecture in order to celebrate the 50th anniversary of the Faculty. Since the establishment of the Construction Chambers I have been a member of the Podkarpackie Regional Chamber of Civil Engineers. I am a member of PZITB branch in Rzeszów and I actively participate in the work of the PZITB Science Committee. I am also a member of the Polish Safety and Reliability Association. For several years I have been a guardian of the Youth Circle of the PZITB branch in Rzeszów, with which I organize various local and national events. One of the most important organizational undertakings was the organization of the 17th edition of the National Congress of Scientific and Technical Young Personnel of PZITB on 26-28 May 2017. I was also one of the jurors in the committee evaluating the 30th edition of the Knowledge and Building Skills Olympiad in Rzeszów in 2017.