SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

Appendix 2b

Piotr Jaskuła, MSc, PhD

Contents

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Gdańsk, 12 November 2018

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

1. Name and surname

Piotr Jaskuła

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

- Doctorate in technical sciences, Faculty of Civil and Environmental Engineering, 2004, title of the thesis: „Analysis of destructive impact of water and frost on asphalt mixtures".
- Master of Science in Engineering, Gdańsk University of Technology, Faculty of Civil Engineering, 1996.

3. Information regarding previous employment at scientific units

- Assistant Professor at the Highway and Transportation Engineering Department, Faculty of Civil and Environmental Engineering, (present) since 1 November 2004.
- Assistant at the Highway and Transportation Engineering Department, Faculty of Civil and Environmental Engineering, from 1 May 1996 to 31 October 2004.

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

4.1. Title of the scientific achievement

Asphalt layer bonding in multi-layered road pavement systems

4.2. Author, title, year of publication, name of the publishing house, publication reviewers

Piotr Jaskuła, „Asphalt layer bonding in multi-layered road pavement systems", Monograph series 172, Wydawnictwo Politechniki Gdańskiej (Gdańsk University of Technology Publishing House), Gdańsk 2018, ISBN 978-83-7348-744-4

Publication reviewers:

Dariusz Sybilski, MSc, PhD, DSc, Prof., Road and Bridge Research Institute

Piotr Mackiewicz, MSc, PhD, DSc, Wrocław University of Science and Technology

4.3. Discussion of scientific goal of the work and the achieved results, including discussion of their use

Scientific goals and achievements

The main purpose of the work was to identify and analyse the chosen factors affecting the strength of bonding between asphalt layers as well as to verify the impact of their inter-layer bonding on performance of the entire pavement structure. I verified the performance of pavement structures in field by assessing pavement deflections and stiffness moduli of the asphalt layers, as well as by comparison of the deflections measured in field with the values from numerically modelled pavements. Moreover, I established guidelines for modelling of inter-layer bonding in mechanistic analyses of pavement structures. I conducted a comprehensive laboratory research program of direct shearing of two-layer cylindrical specimens – both laboratory-prepared and cored from existing pavements – and performed numerical analyses of various pavement structure models, utilising the data from the laboratory research.

In order to achieve my primary goal, I completed a number of intermediate goals, including:

1. Preparation of laboratory workstation for testing of inter-layer bonding using Leutner method. In contrast to the original Leutner method, I individually customised the distance between the shearing clamps in order to avoid shearing of aggregate particles. I also introduced removable grips and clamps to enable shearing of specimens of varying size and shape.
2. Development of method of preparation of two-layer specimens for inter-layer bonding tests to maximally reflect the field conditions, including the process of roller compaction and application of inter-layer coat with airbrush spraying.
3. Identification of factors that affect the inter-layer bonding strength, based on analysis of results from monotonic and cyclic loading of samples, both prepared in the laboratory and cored from pavements.
4. Construction of a full-scale test section of pavement where various levels of inter-layer bonding were simulated in a system of asphalt layers.
5. Identification of inter-layer bonding in field, on chosen existing pavements where premature distress was noted.
6. Detailed analysis of inter-layer bonding inspection test results from all road projects constructed in Poland in the years 2012-2013 across the main road network.
7. Performance of numerical analyses of pavements using the laboratory and field data as well as identification of the optimum analytical model that would best reflect the state of stress, strain and deflections in the pavement.
8. Development of practical guidelines for contractors and supervisors of road projects, leading to improvement of inter-layer bonding and minimising the risk of its deficiencies.

At the time when I started the planned research on asphalt layer bonding in pavement structures, the issue – apart from the consensus of scientists and practitioners that the matter was significant – was still completely uninvestigated in Poland.

The only known and used method of inter-layer bonding assessment at the time was the pull-off method, originally used in quality testing of insulation or industrial floors. The testing conditions or factors affecting the strength of the bonding were unknown. Calculative models in all commonly used pavement design methods assume full bonding of adjacent layers, and especially – full bonding of asphalt layers. Insufficient knowledge of the matter as well as lack of commonly recognised control methods and criteria for bonding in road pavements made acceptance of new and reconstructed roads very difficult. At the same time, there were no explicit guidelines for including the changing bonding strength in structural analyses or allowing for possible influence of limited bonding on pavement life. Therefore, due to significance of the problem and the fact that there are many new road sections being constructed in Poland, it was advisable to perform a detailed research of inter-layer bonding, including the factors that affect it, the methods of its testing and modelling, as well as the means of its improvement.

Characteristics of the monograph

The monograph is the result of many years of my research as well as the effect of my participation in the efforts for introduction of practical solutions that would lead to improved inter-layer bonding in pavement structures. Apart from the review of current knowledge, I performed a comprehensive research program, both in laboratory and in field, and complemented the study with a part focused on pavement structure modelling, taking into account both full and limited inter-layer bonding. In the sections devoted to research, I described my laboratory shearing tests of two-layer asphalt mixture specimens under both static and cyclic loading, which allowed me to identify many factors that have impact on inter-layer bonding. My observations were largely confirmed by full-scale research on the test section as well as analysis of wider field data. In the section devoted to analytical modelling, I presented the use of multi-layered elastic half-space model with the potential of taking into account variable inter-layer bonding strength. Moreover, I presented the use of finite element method, which enables more direct use of data obtained from laboratory tests for calibration of limited bonding models.

The monography consists of eight chapters, in which the results of my works on asphalt layer bonding in road structures are described. The results of laboratory and field research as well as numerical analyses with varying inter-layer bonding strength are presented.
Chapter 1 presents an introduction to the issue of inter-layer bonding. Chapter 2 is a review of state of knowledge on the subject, where the developments in scientific and test works, both in Poland and worldwide, are presented. The mechanism of inter-layer bonding is defined and the effects of its lack on the performance of the entire structure are described. Various factors affecting the inter-layer bonding as well as methods for assessment and analysis of their impact are presented. I observed that the compaction method of two-layer specimens for direct shearing tests affected the results to a great extent. Therefore, development of laboratory specimen preparation method that would optimally reflect the actual compaction conditions (that is: roller compaction) was of crucial importance. I also concluded that the influence of various factors measured in the laboratory had to be verified in full-scale field research. Moreover, analytical modelling of pavement without field verification would have been less dependable in confirmation of the assumed premises. The review of the available knowledge resulted in formulation of research goals as well as the scope of the necessary intermediate steps that are listed above in this summary. Chapter 3 presents my motivation for pursuing this particular research matter, along with the purpose and scope of the work.

Chapter 4 contains the results of laboratory direct shearing tests performed in accordance with the Leutner method (which I modified to some extent). The samples were prepared in the laboratory, using different compaction methods: roller with or without vibration, as well as plate and gyratory compactor. The research encompassed various types and quantities of tack coat. This chapter presents the characteristics of inter-layer bonding under monotonic loading according to shearing force, shearing displacement, shearing strength, shearing stiffness and shearing energy. Shearing tests of single asphalt layers were performed as well, which proved that strengths obtained in inter-layer shearing may reach levels comparable to strengths yielded by a single, homogeneous asphalt layer under shearing. Results of shearing under cyclic loading in a scheme of controlled stress were presented as well. These results enabled the analysis of inter-layer bonding fatigue characteristics. I concluded that the applied inter-layer tack coats should comprise of bitumen emulsions produced from bitumens of penetration less than 100 penetration units as well as bitumens of higher viscosity (modified bitumens), which considerably improve the inter-layer bonding. I observed that – under the condition that all the technological requirements and guidelines are strictly followed – it is possible to obtain inter-layer bonding strengths comparable to shearing strengths of single, homogeneous layers. Comparison of laboratory and field research indicated that effective compaction of the asphalt layers – especially the upper layer – is crucial to inter-layer bonding strength. Use of vibration during rolling of the upper layer may even double the inter-layer shearing strength, as compared to layers rolled without vibration. Shearing strengths of laboratory specimens compacted using various methods differed by up to 100%. It was also observed that a change in the particle size distribution of the mixtures in adjacent layers facilitates better penetration of particles from the upper layer into the lower layer, thus activating the interlocking mechanism between the layers and improving their bonding. In tests of cyclic shearing of specimens it was observed that there is a correlation between the tack coat and improvement of fatigue life at high levels of induced shearing stresses. Moreover, at lower levels of shearing stresses there is a correlation between the effectiveness of asphalt layer compaction (heightened by the use of vibration during rolling) and improvement of fatigue life of the bonding.

Chapter 5 is devoted to research and analyses that I performed on a specially-constructed test section of road pavement, where various levels of inter-layer bonding were simulated in full scale. The test section was divided into specific sub-sections, reflecting different conditions of bonding between asphalt layers. Strength of inter-layer bonding was identified and the impact of its changes on pavement deflections under FWD plate was investigated. Based on the measurements, characteristic stiffness modulus values of the asphalt layers were backcalculated. Chapter 5 presents also the analysis of inter-layer bonding results from tests performed on other real road projects where premature distress was reported.

The analysis encompassed approximately seven thousand records of inter-layer bonding strength measured using Leutner method, obtained from the monitoring system introduced by the central road authorities on newly constructed sections of national roads, expressways and motorways. In this chapter I also performed an analysis of inter-layer bonding criteria used in Poland and proposed recommended criteria, taking into account three aspects: theoretical distribution of shearing stresses in pavement structure, the current inter-layer bonding criteria used in other countries worldwide, as well as the real distribution of actual results obtained. Construction of the full-scale test section enabled the assessment of pavement performance with insufficient inter-layer bonding – especially in terms of bearing capacity. I concluded that lack of inter-layer bonding resulted in reduction of bearing capacity, as compared to sections where full inter-layer bonding was observed. Moreover, ignoring of limited inter-layer bonding in backcalculations of stiffness or elastic moduli of pavement layers leads to underestimation of the moduli, design of unnecessarily thick overlay and underestimation of its potential fatigue life. It was evident on the test section that the use of tack coat from bituminous emulsion produced from bitumen softer than the bitumens used in the two adjacent layers (in this case: 70/100 and 35/50) significantly reduced the inter-layer bonding in comparison to situation when the same two courses were laid without any tack coat. Moreover, application of tack coat from emulsion containing soft bitumen 160/200 resulted in an adverse phenomenon – reduction of inter-layer bonding strength with time. It was also noted that the inter-layer bonding in a pavement under traffic will not improve in time, unless at least a limited initial bonding was provided during construction. Improvement of inter-layer bonding with time may be expected if the initial shearing strength of the interface was not lower than 0.4-0.5 MPa.

The analysis of 7043 records of inter-layer bonding tests on newly constructed roads within the Polish main road network in the years 2012-2013 allowed me to conclude that on the roads that are characterized by the highest technical standards as well as the highest level of quality control, a very good bonding between the wearing and binder course is achieved, while the number of results that do not meet the requirements is very low (only a few percent of cases). In contrast, assessment of inter-layer bonding between the binder course and the asphalt base, or between two lifts of the asphalt base course, showed that the percentage of cases that failed to meet the requirements was higher and exceeded ten percent. I observed in my analyses that a particle-size distribution difference between adjacent layers (that is – finer mixture in the upper course and a coarser mixture in the lower course) results in lower number of specimens with insufficient bonding. This effect is due to better interlocking when the hot, finer course is laid over the cold, coarser mixture. I concluded that in the case of interfaces between lower asphalt layers (binder course-base course or base course-base course) it is absolutely crucial to introduce a difference in particle size distribution between adjacent layers as well as to avoid using mixtures with high diameter of the largest particles. In the case of interface between the wearing and binder course, as well as between the binder and base course, an evident relation was observed between the inter-layer bonding and the compaction index of the upper course. I did not observe the same relation in the case of base courses laid in two lifts, that is two mixtures with the same particle size distribution.

The criteria that I ultimately proposed for inter-layer bonding tested using Leutner method at the temperature of +20°C for the interfaces of wearing and binder course, binder and base course or two lifts of the base course, are 1.0 MPa, 0.7 MPa and 0.6 MPa respectively. They were assumed with an adequate safety margin (2-3 times), resulting from the theoretical distribution of shearing stresses at the depths of particular interfaces between the asphalt layers; they also reflect the level of current inter-layer bonding requirements used worldwide and guarantee acceptable values of actual inter-layer bonding strength measured on roads constructed in Poland.

The next part of the work is devoted to modelling of pavement structures with various levels of inter-layer bonding (chapter 6) and includes numerical analyses that reflect the impact of lack of bonding on pavement life for structure types KR3 (moderate traffic) and KR7 (heavy traffic) as well as the impact of changes in inter-layer bonding on pavement deflections. The numerical analyses included adequate simulations encompassing various tack coats and levels of inter-layer bonding strength within the structure. Calculations that were performed using the BISAR software included analyses of the effect of depth of lack of bonding in pavement types KR3 and KR7 on fatigue life as well as the influence of inter-layer bonding on pavement deflections. These analyses were preceded with calculations that calibrated the coefficient of layer bonding stiffness in the BISAR software. Finite element method analyses were performed as well, using the ABAQUS software. FEM enabled the use of various models of contact at the interface between layers, such as: full bonding, full slide, contact with friction or contact with cohesion. The most advanced model of interaction at the interface included two phases of performance: the first phase of interaction was based on cohesive contact with elastic characteristics, while the second phase (after bonding failure) was based on friction.

Based on the performed numerical analyses, I concluded that the bonding between asphalt layers has a crucial effect on the overall state of stress and strain within the road structure. Faulty inter-layer bonding leads to reduction in the stiffness of the whole asphalt multi-layered system, thus increasing its deflections, which generate greater horizontal strain at the bottom of the asphalt layers, reducing the fatigue life of pavement structure. I observed that the BISAR software can be used to model inter-layer bonding: either through parametric introduction of lack of bonding (full slide) or full bonding, or through calibration for adequate reflection of partial bonding. By assuming suitable levels of bonding coefficient, it is possible to describe the inter-layer bonding in terms of percentage, which may prove useful in approximate calculations, but still does not reflect the exact state of stress and strain. The numerical analyses in BISAR software showed that the factor that has a major impact on reduction in pavement life is the depth at which lack of inter-layer bonding occurs. In the KR7 pavement the most vital location in terms of potential fatigue life reduction of the whole structure is the interface between the binder course and the base course, while in the case of KR3 pavement the most important place is the interface of the wearing and binder course. Lack of inter-layer bonding contributes to reduction in bearing capacity, whose characteristic indicator is the deflection of pavement. When the level of bonding was limited, an increase by 20% to 60% in pavement deflection was observed, which was caused, among others, by a reduction in the stiffness of the entire multi-layered system.

Theoretical calculations of pavement deflections were confirmed by FWD dynamic deflectometer measurements on the test section, where lack of inter-layer bonding was forced. Omitting of faulty inter-layer bonding in backcalculations (calculations of elastic modulus values of structure layers based on deflection basin) later results in design of overlay that is too thick and therefore does not use the full potential fatigue life of the pavement.

Newer versions of the ABAQUS software contain a library with various implemented models of bonding on the interface between two materials: the full bonding “tie” model, contact with sliding, contact with cohesion, contact with friction as well as a complex model that incorporates cohesion and friction. The two models that are the most appropriate for pavement analysis are: the “tie” model for full inter-layer bonding and the complex model for limited bonding. In the latter, the limiting values for the cohesion-based performance phase may be set directly on the basis of Leutner laboratory tests – tangent stiffness as shearing strength divided by displacement under shearing. Validity analyses of models used in finite element method by means of calibration against deflections measured in the field indicated that limited inter-layer bonding is best simulated by the complex model. Measured and calculated deflection basins of the loaded pavement are best matched in this case. In contrast, it was impossible to match the measured and calculated deflection basins when the pavement was modelled using the BISAR software with layer interface properties reflecting lack of bonding or limited bonding.

In the next part of the work, chapter 7, I presented my practical guidelines for improvement of inter-layer bonding and reduction of risk of limited bonding. They pertain to tack coat, characteristics of adjacent layers as well as environmental and service conditions. If problems with ensuring correct bonding strength occur during construction of a project, inspection efforts should be intensified in order to verify particular factors that may affect the bonding strength.

The work ends with summary (chapter 8) presenting key conclusions from the laboratory and field research as well as from the numerical analyses. Further objectives in the field of inter-layer bonding are proposed, that is: development of quick laboratory method for evaluation of bonding strength under cyclic loading, development of non-destructive field method for bonding strength assessment as well as improvement of pavement structural analysis methods to take into account the reduced inter-layer bonding using widely available tools for mechanistic calculations.

Summary of the monograph

The primary achievement and contribution of the monograph to the discipline of civil engineering is the indication of the most significant factors affecting the bonding of asphalt layers and verification of the impact of inter-layer bonding on deflections of real pavement structure.

The monograph, constituting the scientific achievement, presents an extensive laboratory research, whose results are characterised by low variability. I have definitely proven that the type of emulsion used for tack coat – and primarily the viscosity of bitumen used in the emulsion (hard, soft; modified, unmodified) – is of decisive importance to the level of inter-layer bonding, due to activation of sticking mechanism.

The effectiveness of compaction of upper courses improves the strength of inter-layer bonding. A difference in aggregate particle size distribution between adjacent asphalt layers also positively influences the inter-layer bonding due to activation of interlocking mechanism. The original contribution of my work is the use of the results of cyclic loading shearing tests. It enabled me to note that at higher levels of shearing stress at the interface of asphalt layers the bituminous emulsion tack coat is of dominant importance, while at lower levels of shearing stress good interlocking of the two courses is more significant.

My original research at the test section of a full-scale road pavement, where I simulated various levels of bonding between the binder course and the asphalt base, made it possible to measure the bearing capacity of the entire structure at different levels of inter-layer bonding that I introduced under controlled conditions. Tests performed with an FWD deflectometer showed significant differences between the test section parts with full bonding and lack of bonding. The test results also led me to definitive conclusion that ignoring of lack of inter-layer bonding in backcalculations leads to significant underestimation of the searched value of stiffness modulus of the entire asphalt layer system. Since this modulus is later used in pavement overlay design process, its underestimation negatively affects the analytical results of pavement fatigue life.

In my numerical analyses of road pavement structures using the theoretical model of multi-layered elastic half-space (which is the one most often used in pavement design) I noticed that the model enables the assumption of various inter-layer bonding levels: not only full bonding and lack of bonding, but intermediate states as well. Nevertheless, an earlier analytical calibration of the model is needed. I concluded that in thick asphalt pavements (for traffic categories KR5-7) the decisive factor in terms of fatigue life is the bonding between the binder course and the asphalt base. In pavements for lighter traffic (KR1-3), with lower total thickness of asphalt courses, the most important factor is the bonding between the wearing course and the binder course. In numerical analyses using the finite element method in commercial software ABAQUS I noted that it is advisable to model the inter-layer bonding in two phases, that is: assume cohesive behaviour until the shearing strength at the interface is exceeded and later, after shearing failure, assume friction. I obtained the parameters needed for the two-phase model from the earlier laboratory research. At the same time, thanks to full control of inter-layer bonding during the construction of the test section, I calibrated the chosen numerical model based on tests of real, full-scale pavement – which is not common and constitutes a technical novelty. The results of calculations using the calibrated two-phase model proved the closest to the deflection basin measured in field. An increase in pavement deflections when a lack or fault of inter-layer bonding is assumed may reach 20% to 60% as compared to pavement with full bonding.

In the work I have also shown that my conclusions from the performed laboratory research regarding inter-layer bonding and its dependence on emulsion type, compaction and aggregate particle size distribution of the asphalt mix were supported by the observations of real pavements constructed in Poland. It is vital to introduce a difference in particle size distribution between two adjacent layers, especially in thick asphalt base that is often laid in two lifts. It is advisable to introduce at least a slight difference in particle size between the upper and lower lift of the asphalt base.

The methodology of inter-layer bonding testing used in the work is useful for evaluation of factors that affect the strength of bonding between asphalt courses. The used numerical analyses should contribute to development of awareness and further research of road pavement inter-layer bonding. Moreover, the pavement model that has been verified in field and uses the advanced calibrated model of inter-layer bonding with limiting values based on laboratory test results may be useful in prediction of pavement performance with faulty inter-layer bonding. The work also includes clear practical guidelines for minimisation of risk of lack or limitation of inter-layer bonding.

5. Summary of other scientific and research accomplishments

5.1. Scientific activity

In the following part of the summary of professional accomplishments I discuss the remaining scientific activity, referring to works from the list of published scientific papers – Appendix 3. I have distinguished the following subject groups:

1. *Studies and assessment of influence of environmental factors on asphalt mixtures and their performance in pavements.*
2. *Studies and assessment of influence of additives and modifiers on asphalt mixture properties.*
3. *Studies and numerical modelling of flexible pavements, including the influence of traffic, temperature and types of materials used.*
4. *Problems of modelling of road, industrial and port pavement structures in search of optimised structural solutions.*

5.1.1. Studies and assessment of influence of environmental factors on asphalt mixtures and their performance in pavements

I developed an interest in the impact of environmental factors – such as water and frost, low and high temperatures or factors contributing to asphalt mix ageing – before I was granted the doctorate in technical studies [II.E.66, 48-64, 45-46]. I pursued studies in this field, which led me to my doctoral thesis, “Analysis of destructive impact of water and frost on asphalt mixtures”, supervised by Józef Judycki MSc, DSc, Prof. The most important achievement in the work was the identification of impact of aggregate type, bitumen type, adhesive additives and asphalt mix parameters (such as compaction index, filler/bitumen ratio) on mixture susceptibility to water and frost action, as well as the impact of high water-frost susceptibility on overall pavement fatigue life. Within this study I developed and field-verified the criteria for asphalt mixture susceptibility to moisture and frost, which were published in 2008 in my first article in a journal from the JCR list [II.B.2]. I confirmed my analyses of impact of moisture and frost susceptibility on fatigue life of asphalt mixtures [II.E.a.12, II.E.c.21] as well as on the life of entire pavement structures, through observation and analysis of distress on real pavements [II.B.1]. I noted that the asphalt concrete base courses are most exposed to destructive impact of moisture and frost, due to large amount of air voids and easy flow of rainwater from the surface and roadside as well as groundwater from the bottom of the structure. Reduction in fatigue life of the asphalt concrete base due to destructive action of moisture and frost may have a decisive impact on the life of the entire structure. The noted reduction in the AC base fatigue life should be taken into account in analyses of long-term fatigue life of the structure. In my studies of mixture susceptibility to water and frost I introduced research methods that were not used in Poland at the time, utilising accelerated sample conditioning in laboratory and simulating the destructive action of moisture and frost based on the American research methods [II.E.c.66, 64, 61]. The influence of low and high temperatures as well as ageing on asphalt mixtures I assessed in laboratory tests, utilising three point bending beam tests at low temperatures or resilient moduli measurements for cylindrical specimens of various asphalt mix types [II.E.c.62, 61, 60, 57-55, 53, 52, 46-45]. Within this research I identified and isolated the influence of chosen properties of the bitumen itself on the performance of asphalt mixtures [II.E.c.58, 54, 51, 50, 48]. In later works I identified the rheological parameters of asphalt mixtures and bitumens at low and high temperatures [II.E.c.13, c.11, b.8, II.E.a.8, II.E.a.4, II.A.7, II.A.4-3], for further direct usage in pavement numerical analyses across the full range of temperatures. I also identified the range of temperatures that asphalt pavements are subjected to and published it in the work [III.E.a.6], in which the service temperatures for various asphalt course types and different regions of Poland were calculated using the Superpave method based on the analysis of temperature measurements from 60 Polish weather stations across 30 years [II.E.a.6].

One of the major subjects in my studies was the identification of precise causes and explanation of pavement distresses that are based on the destructive impact of environmental factors (including low temperatures) on asphalt mixtures [II.A.3, II.E.a.8, II.E.a.10, II.E.b.1, II.E.c.14-15]. Observations from these efforts proved useful also in my investigations within the main field of my scientific work, that is the inter-layer bonding. During coring of samples from pavements it was noted that some transverse cracks visible on the surface had propagated to lower layers, that is to the bottom of asphalt layers and to the mechanically-stabilised crushed aggregate base or cement-stabilised working platform layer. Other cracks were visible only in chosen asphalt layers and had not propagated to lower layers – this was true where bonding between asphalt layers was limited. It was observed that in locations where the surface of the layer was more homogeneous and less porous, smaller number of transverse cracks was visible than in locations with less uniform texture. Sections with courses of high-modulus asphalt concrete showed more intensive low-temperature cracks than sections with typical asphalt concretes. The average observed quantity of cracks per kilometre for high-modulus asphalt concretes was over two times higher than on sections constructed from typical asphalt concretes. It was observed [II.E.a.8] that elasticity modulus of asphalt layers on sections with high-modulus asphalt concretes was two times higher than on sections with typical asphalt concretes.

In the course of the described research I concluded that the original cause of premature distress observed as cracking related to the action of water and frost were predominantly the errors made during the design of asphalt mixture composition. Mixtures with small asphalt content and high filler content were overly stiff, also due to accelerated bitumen ageing, which occurs for such mixture compositions [II.A.1-2, II.E.c.38, 46, 62]. At the same time, the premature low-temperature distress was mainly caused by: use of overly hard bitumens with high stiffness and low relaxation as well as technological errors and faults at the stage of asphalt course construction, including insufficient compaction or allowing segregation of mixtures.

5.1.2. Studies and assessment of influence of additives and modifiers on asphalt mixture properties

Having developed a set of finished research methods for assessment of performance properties of asphalt mixtures, including methods for testing of their susceptibility to water and freezing [II.B.10.a-g], permanent deformations, ageing and low temperatures, I also researched the effect of additives and modifiers on parameters of asphalt mixtures. I confirmed that bitumens modified with polymer or rubber contribute to improvement of properties of asphalt mixtures in terms of performance at low temperatures or resistance to water-frost action [II.B.4, 7, II.E.a4, II.E.c.17, 56, 64-63]. An improvement was noted in low-temperature performance of asphalt mixtures with modified bitumens in comparison to mixtures with unmodified bitumen. The critical strain at failure of asphalt mixture beams subjected to bending at -20°C was two times greater when modified bitumens were used. The effect of polymer fibre reinforcement on asphalt mixture properties was also positive. Compared to mixtures without fibres, a significant improvement was noted in terms of low-temperature performance, while improvement at high temperatures (in terms of e.g. resistance to permanent deformation) was of little significance [II.E.a.2, II.E.c.6]. During fracture tests of asphalt mixtures with fibres at low temperatures, an increase in Rice's J-integral of up to three times was noted in comparison to mixtures without fibres [II.E.a.2]. Other parameters of resistance to fracture initiation and propagation in asphalt mixtures were measured in tests of tension and compression of specimens under cyclic loading at the temperature of +25°C, adapting the American method of fracture resistance assessment. While significant positive effect of highly-modified bitumens was noted [II.E.a.13, II.E.c.6], in some cases an addition of asphalt granulate had a negative influence on asphalt mixture resistance to fracture propagation [III.B.d.1].

In the works [II.E.a.5, II.E.b.7, II.E.c.35-36, 40-41, 46, 59, II.B.9.a-e] I identified and described the multi-functional effect of hydrated lime used as an additive to asphalt mixtures: a reduction in moisture and frost susceptibility, an improvement in resistance to permanent deformation, but also slowing down of ageing process and reduction of mixture stiffening at low temperatures. Hydrated lime proved to be an excellent additive for improving adhesion of bitumen to aggregate, irrelevant of their combination used, and insensitive to high temperatures. It is an important advantage compared to liquid adhesion promoters. After the research works were completed, a short monograph was published, presenting the positive effect of hydrated lime as well as technological guidelines for production of asphalt mixtures with the addition of hydrated lime [II.E.b.7].

5.1.3. Studies and numerical modelling of flexible pavements, including the influence of traffic, temperature and types of materials used

In the field of pavement structure mechanics, I was interested in modelling of pavement structures on low embankment situated over weak subgrade. In the prepared model I introduced many layers of similar character and loaded the model with an entire heavy vehicle with several axles, which allowed me to take into account the overlapping deflection waves from separate axles of the moving vehicle [II.E.c.47]. During modelling I paid special attention to inter-layer bonding in the asphalt pavement and its impact on premature distress [II.E.c.47, II.E.a.7, II.E.a.16, II.F.a.20], resulting in structural deformation in thinner pavements and cracking of asphalt layers in thicker pavements for heavy traffic.

I published the results of analyses focused on the effect of temperature on pavement performance in conference and industry meeting papers [II.E.a.6-11, 15, II.E.b.2].

I made a major contribution to stage preparation of the new Catalogue of Typical Flexible and Semi-Rigid Pavement Structures [II.F.b.4, II.E.c.7, 19, 20, II.E.b.2-3], in which, together with co-authors, I created unambiguous systematisation of pavement layers, encompassing the typical materials used in Poland and including the asphalt courses, whose assumed properties were based on statistical analysis of bitumens produced in Poland.

A large section of my research efforts was devoted to adequate incorporation of Polish traffic data in design: assumption of the parameters of pavement loading and its influence on pavement life [II.E.a.3, II.E.c.22-23, 27, II.E.b.6]. An important aspect in this field is the impact of overloaded vehicles and pavement roughness on reduction in pavement life [II.E.c.4, 8, 12, 16, 22-23, 27, II.A.5, II.E.a.15, II.E.b.9-10], since overloaded vehicles contribute to as much as 35-70% of the total fatigue damage. On average, half of the total fatigue damage is caused by overloaded vehicles. Moreover, deterioration of pavement evenness from class A (very good state) to the lower limit of class B (acceptable state) results in reduction of pavement fatigue life by as much as 30%.

Another important aspect of my scientific activity was the prediction of the impact of passage of an oversized heavy-duty vehicle on flexible pavement life [II.E.a.15, II.E.c.8, 12, F.a.12]. In these works the fatigue damage caused by a non-standard oversized vehicle was obtained using mechanistic calculations of stress and strain within the pavement, whose results served as input for fatigue criteria: AASHTO 2004 for bottom-up cracking and Asphalt Institute for permanent deformation. It was noted that the equivalent number of standard axle loads for a single non-standard heavy-duty vehicle may reach even 321 axles (100 kN). One passage of a heavy-duty vehicle may cause the same destructive effect as passage of approximately 200 typical tractor-trailers.

Moreover, in my scientific activity I devoted much effort to modelling of semi-rigid pavements, where the asphalt courses are laid on a base of hydraulically bound materials. Such base significantly changes the mode of performance of the entire pavement [II.E.a.9]. Design of a semi-rigid pavement calls for careful consideration of seasonal temperature changes. In the summer, when the asphalt layers are less stiff, higher stresses are generated under loading in the hydraulically bound layer. The fact that fatigue life is significantly reduced in this season should be taken into account in calculations of fatigue damage. It is necessary to design the asphalt layers thicker by 2-3 cm in total, in order to ensure the same fatigue life as the one calculated for a single equivalent temperature. Shrinkage cracking of the hydraulically bound base is an inevitable phenomenon in semi-rigid pavements. It leads to reduced load transfer at the cross-sections where cracking occurred. A reduction in load transfer by 20-30% results in the necessity of a further increase in the total thickness of asphalt layers by 3 cm in order to retain the fatigue life on the same level as for uncracked base.

5.1.4. Problems of modelling of road, industrial and port pavement structures in search of optimised structural solutions

Another subject matter that interests me in my scientific development is the pavement structure optimisation by using analytical modelling in order to choose the appropriate materials or layer system, depending on the configuration of untypical loading. Detailed analysis of stress and strain induced by heavy-duty port vehicles or aircraft – as well as standard vehicles in road traffic – enables introduction of informed modifications to typically designed pavement systems. It also enables the use of site-won or untypical materials. Such analysis is also helpful in verifying whether potential errors or deviations from acceptable ranges would result in premature failure in the case of a particular pavement.

In example, a change in the designed concrete pavement, introducing paving concrete blocks, in the port in Gdańsk contributed to reduction of project costs by 12%. The change was supported by numerical analyses. In this particular pavement design, specific properties of many layers were taken into account: multi-layered base of hydraulically-bound aggregate, abrasion-resistant sand bedding from material obtained from riverbed dredging as well as subgrade improved with uniformly-graded material from seabed dredging [II.B.2, II.F.a.10].

In another case of road pavement modelling it was noted that changes in pavement fatigue life due to changes in stiffness moduli and bitumen content of asphalt mixtures were minor and could reach approximately 4%. In contrast, the greatest impact on pavement life was associated with changes in overall asphalt layers thickness and changes in air void content of the asphalt base – the increase in pavement life could reach 25% in the case of increase in the overall asphalt layer system thickness by 1 cm, and 45% in the case of reduction in air void content by 20% [II.F.a.3].

Due to taking into account the individual stiffness and fatigue characteristics of asphalt mixtures with modified bitumens it was possible to increase the motorway pavement fatigue life by nearly 30% [II.B.4.d, III.B.d.9]. Fatigue life of the pavement with total asphalt layer system thickness of 27 cm and modified bitumen used only in the wearing course equalled almost 13 million 115 kN standard axle loads. Usage of modified bitumen in both wearing and binder courses resulted in fatigue life improvement to 17 million 115 kN standard axle loads.

In this section it is necessary to mention again my contribution to work on the new Catalogue of Typical Flexible and Semi-Rigid Pavement Structures (2014), which, apart from choice of appropriate pavement model and performance of essential mechanistic analyses, also called for a deeper analysis of the optimum use of failure criteria, encompassing the behaviour of hydraulically-bound layers [II.E.b.2, III.I.f.5], and interpretation of criteria result sensitivity to changes in strength of hydraulically-bound materials and the used load transfer coefficients for locations around the cracks.

Summary

While my scientific activity within the aforementioned fields is quite diverse, it is mostly focused on material-related issues and the use of material properties measured in laboratory and in field for modelling of pavement structures. In my calculations I use not only the basic techniques of pavement modelling based on multi-layer elastic half-space, but also FEM. I contributed to the domain of civil engineering by identifying the influence of different materials – and their changes due to environmental factors – on performance of pavement structure as well as by developing pavement models that enable scientific verification of impact of various materials on the fatigue life. I used the presented scientific achievements in preparation of numerous technical and scientific expert reports commissioned by the industry and road administration.

My scientific achievements include 61 publications (1 monograph, 7 JCR list articles, 11 chapters in books, 43 other peer-reviewed publications including conference papers). The total Impact Factor (IF) of these publications in the year of publishing according to the JCR list is IF = 12.878. A significant part of my works has been indexed in the Web of Science (WoS) and/or Scopus bases. The total number of citations equals 77 according to WoS and 82 according to Scopus. Hirsch index equals 6 according to WoS and 5 according to Scopus base. A detailed list of publications can be found in Appendix 3, whereas item 7 of this summary (Appendix 2a) includes a parametric listing. The total number of points for publications authored after granting of the doctorate, according to the Ministry of Science and Higher Education (MNiSW) parametric assessment, equals 543.

5.2. Activity in the field of completed design, construction and technological achievements, research works, expert opinions and research projects

Publications concerning this activity were listed in Appendix 3 in the items: II.B, II.F, II.J. Works that pertained to wide subject matter and required considerable involvement of many co-authors are particularly noteworthy. My contribution to these works is presented in Appendix 3. In some cases my contribution is limited to one or several chapters of the report, while in other cases it is distributed over the whole text and thus difficult to isolate.

One of such noteworthy major challenges was the verification and updating of the Catalogue of Typical Flexible and Semi-Rigid Pavement Structures, commissioned by the General Directorate for National Roads and Motorways (GDDKiA) and performed in the years 2009-2013 [II.B.1]. For the first 2 years I coordinated all the activity of the entire author team, and for the last year I coordinated the efforts jointly with the head of the project. I performed analyses of materials and technologies suitable for typical pavements. I took part in development of axle equivalency coefficients for calculations of design traffic. I performed numerical analyses of the main (upper) pavement structure layers and co-analysed the team's solutions for the lower layers (layers that serve the improvement of subgrade). I coordinated the consultations of the catalogue with road industry representatives. I participated in preparation of the final report, the final version of the catalogue as well as the book that documented and explained the assumptions and stages of the work. In 2013 I was responsible for consultations with the GDDKiA and the Ministry of Infrastructure and Construction regarding the final version of the catalogue as well as the newly introduced provisions of the regulation establishing basic technical requirements which should be fulfilled by public roads in Poland.

Another field of my activity was the development and nation-wide introduction (2013) of the instruction for testing of bonding between asphalt layers, including assessment criteria [II.B.3]. This work required laboratory verification of the proposed procedure, along with comparative analysis of the bonding criteria against the actual bonding results from tests performed at real road projects in Poland.

My major design achievements included the contribution to design works of pavement for the Deepwater Container Terminal II (DCT II) in Gdańsk as well as numerous expressway pavements across Poland [II.B.2, II.B.5]. In the case of the container terminal pavement, I was the head of the design team. I co-authored numerical analyses of pavements subjected to loading from port vehicles and containers, including optimisation of materials used for particular layers. I took part in negotiations of introduction of alternative technology with the investor and supervisor. I co-authored the final report. I was a consultant for the contractor during the construction works in the port. In the case of expressway pavements my contribution included analysis of properties of materials considered for use in expressway construction and performance of mechanistic calculations of flexible and rigid pavements, taking into account the impact of subgrade strength, thickness of base layers, inter-layer bonding and equivalent temperature. I also took part in the process of verification and acceptance of the recommended pavement designs by the GDDKiA and Construction Supervision experts. In most projects I was the head of the design team.

Other original works included the design of flexible pavement structures on the A1 toll motorway on sections: Gdańsk-Nowe Marzy and Nowe Marzy-Toruń. It was the first (2005-2006) case of use of high fatigue resistance asphalt base as well as stage design of pavement structure based on mechanistic-empirical methods in Poland [II.B.IV]. My contribution included the analysis of properties of materials considered for use in motorway construction, performance of pavement mechanistic analyses (encompassing the effect of subgrade strength, thickness of the base layers, bitumen type used, pavement equivalent temperature, filter layer parameters) as well as participation in the process of verification and acceptance of the design by the supervising consultant from the Atkins company as well as experts representing the licensee (GTC) and the GDDKiA.

Another original work was the earlier (2001-2002) design of semi-rigid pavement structure on the A2 toll motorway [II.B.6] on sections: Września-Konin, Komorniki-Nowy Tomyśl and Krzeniny-Września. It was the first case of use of stage design and stage construction of pavement structure in Poland with design assumption verification by means of full-scale testing using the Heavy Vehicle Simulator HVS (first use of advanced HVS in Poland). During this project I had the opportunity to work alongside the most prominent European experts in the field of design and full-scale testing of pavements. These works resulted in acceptance of the recommended design premises as well as the calculated critical strains that determined the final thickness of layers of the semi-rigid pavement structure on the A2 motorway.

Other works that I participated in were devoted to introduction, on the national level, a previously unused method for testing of asphalt mixture susceptibility to water and frost [II.B.10]. The works resulted in development of testing procedure and the criterion for asphalt mixture assessment in this regard. In consequence the GDDKiA introduced the guidelines in technical specifications for projects that were realised at the time, in 1996-2002. In the aforementioned works I reviewed the moisture and frost susceptibility assessment methods used worldwide and performed the tests in accordance with the American methods using the NAT testing device, which was a novelty at the time. I also took part in the design and verification of asphalt mixture recipes. I coordinated and supervised the laboratory tests.

A noteworthy segment of my works consists of the efforts in the years 1998-1999 that to some extent contributed to nationwide return – after 20 years – to the use of hydrated lime as an adhesive additive to asphalt mixtures [II.B.9]. I also contributed to introduction of blast furnace slag in road bases in the Northern Poland region of Pomerania in 2000 [II.B.7]. In these works I participated in planning of research programs and performed the laboratory and field tests. In the case of use of hydrated lime I participated in development of dosage methods.

In the years 1996-1997 I significantly contributed to development and introduction of technology for production of polymer-modified bitumens at the Gdańsk Refinery (the first industrial-scale modified bitumen production project in Poland) through assessment of their performance in asphalt mixtures as well as development of colloidal stability control [II.B.8]. I participated in the design and construction of a 30-liter container for modified bitumen colloidal stability assessment that enabled bitumen sampling from three different levels.

Apart from the presented participation in design and technological works, in the years 1996-2018 I contributed to a total of 117 expert reports and research works, including 37 expert reports and research works in which I was the head of the research team (in the years 2014-2018). Many of these works were significant, not only to the discipline of civil engineering, but also to the economy. The most important works include:

- scientific expert reports that enabled realisation of vital road projects on the national level [II.F.a.1-II.F.b.3],
- pavement design and technological methodologies [II.F.b.-5, II.F.b.10, 15-16],
- research efforts that facilitated introduction of new products by numerous road material producers [II.F.b.6-9, 11-14, 17-25].

To date I have participated in two research projects (2016-2018) completed within the scope of the national research program of Road Innovation Development (RID) and jointly commissioned by the GDDKiA and the National Centre for Research and Development (NCBiR). In both projects I was the head representative of the Gdańsk University of Technology which was a partner in both scientific consortiums. The projects were entitled: "Road and modified bitumens in Polish climatic conditions" [II.J.a.2] and "Utilisation of recycled materials" [II.J.a.3]. As a co-author of the reports that summarised the conducted research, I emphasised the significance of the binders used in terms of performance properties of asphalt mixtures at low and medium temperatures. I also co-authored new requirements for road bitumens. In the project pertaining to recycling I co-authored three instructions for the use of asphalt granulate in the design and production of mixtures using hot recycling.

Currently (2018-2020) I am taking part in the national research project TechmatStrateg, commissioned by the NCBiR. I am the head representative of one of the partners within the scientific consortium responsible for material and road structure analyses. The name of the project is "Safe, ecological and poroelastic road structures" [II.J.a.1]. I participate in design of poroelastic mixtures with 30% content of granulated rubber instead of mineral aggregate and high content of highly-modified bitumens. I was also the leader of the scientific consortium in the finished (2016-2017) stage research project commissioned by the Lotos Asfalt company and devoted to long-life pavements with highly-modified bitumens [III.F.1].

The total number of major works in the field of design, construction and research achievements [B, F, J] after granting of the doctoral degree equals 117, including 37 works where I was the head of the project.

6. Information on didactic achievements, scientific cooperation, domestic or foreign internships and popularisation of science

As a research and didactic worker at the Faculty of Civil and Environmental Engineering at the Gdańsk University of Technology I have been carrying out the didactic programme, including the following classes at BSc and MSc studies (both full-time and part-time courses) as well as MSc studies in English: Transportation Infrastructure Diagnostics, Road Materials, Construction of Roads and Motorways, Road Construction Technology, Road Materials Engineering, Transportation Engineering (lecture in English), Earthworks, Road Maintenance, Roads and Streets, Traffic Studies in Transportation, Airport Pavement Structures as well as Diploma Seminars. My didactic effort exceeds the set requirements for obligatory teaching hours. The number of BSc and MSc degrees granted to students that I supervised reaches 142. I participated in committees responsible for preparation of study programmes (syllabuses, the effects of instruction, examination questions). I was also the year tutor at the Civil Engineering major.

In the following part I characterise the chosen information listed in Appendix 4. I was a peer-reviewer at 6 national and international conferences [III.C1]-[III.C6]. I am the member of the scientific editorial board of the specialist journal "Nawierzchnie Asfaltowe". I received 15 awards and distinctions, [II.K1]-[II.K12] and [III.D1]-[III.D3]. I am the member of 6 scientific organisations, including 3 international organisations [III.H1]-[III.H6]. I would like to emphasize my efforts in the field of popularisation of science, especially at the Baltic Science Festival [III.I.2] and road construction workshops and lectures [III.I.f-g]. I also take part in other initiatives at my faculty and university, devoted to didactics and organisation, listed under position [III.Q].

In the periods of 2013-2015 and 2014-2016 I offered scientific assistance as an auxiliary supervisor of two successful doctoral procedures at the Faculty of Civil and Environmental Engineering at the Gdańsk University of Technology [III.K.a]. Currently I am an auxiliary supervisor of a third procedure. I completed four practical internships in the field of road construction [III.L1]-[III.L4]. I was the member of two expert teams [N1]-[N2]. I am an active peer-reviewer in four JCR list journals with Impact Factor: Journal of Testing and Evaluation [III.P.a.1], Construction and Building Materials [III.P.a.2], Engineering Structures [III.P.a.3], Road Materials and Pavement Design [III.P.a.4]; along with others that do not have Impact Factor: Drogownictwo, Roads and Bridges - Drogi i Mosty, Advance in Civil Engineering, International Journal of Pavement Research Technology, Journal of Traffic and Transportation Engineering (English Edition), International Journal of Technology, Archives of Civil Engineering, Transportation in Developing Economies. I am also a peer-reviewer at six international conferences [III.P.b] To date (October 2018) I have reviewed 27 journal articles (including 7 from the JCR list) and 26 international conference papers.

7. Parametric summary of scientific achievements

A detailed list of all the published scientific and professional works is presented in Appendix 3. Tables 1 and 2 include a summary of my scientific, didactic and popularising activity, including the total number of achievements (Table 1) and number of points according to the list of Ministry of Science and Higher Education (MNiSW) for publications after granting of the doctorate (Table 2). The total number of points for publications after the doctorate, taken into account by the MNiSW in research unit assessment, equals 543 (583)* points, taking in to account the percentage of contribution the total number of points is equal to 198 pkt.

Table 1. Summary of scientific achievements (according to Appendix 3 – as of 11 November 2018)

Type of achievement	Total number of achievements	Designation according to Appendix 3	Number of achievements after doctorate
Habilitation monograph	**1**	I.B	**1**
Scientific publications in journals from the Journal Citation Reports (JCR) database	**7**	II.A	**7**
Monographs and chapters in monographs in Polish	6	II.E	6
Monographs and chapters in monographs in English	5	II.E	5
Scientific publications in journals from the MNiSW B list	31	II.E	28
Other peer-reviewed scientific publications in journals or conference materials	36	II.E	15
Total number of publications	85		61
Scientific publications in national or international journals indexed in the Web of Science database	7 JCR+10 (14)*		7 JCR+10 (14)*
Scientific publications in national or international journals indexed in the Scopus database	14		14
Papers presented at conferences abroad	13	II.L	11
Papers presented at conferences in Poland	24	II.L	13
Total number of the MNiSW points (in the year of publication)	555(595)*		543(583)*
Total Impact Factor (in the year of publication)	**12,878**	II.G	**12,878**
Number of citations according to the WoS database	**77**	II.H	**77**
Number of citations according to the Scopus database	88	II.H	88
Number of citations according to the Google Scholar database	333	II.H	-
Hirsch index according to the WoS database	**6**	II.I	**6**
Hirsch index according to the Scopus database	5	II.I	5
Hirsch index according to the Google Scholar database	10	II.I	-
Design, construction and technological achievements	11	II.B	8
National patents granted	0	II.C	0
Completed research works, expert opinions and other commissioned reports:			
- as the head of the team	37	II.J	37
- as a member of the team	167	II.J	80
Participation in national research projects:			
- as the head of the team	4	II.F	4
- as a member of the team	21		9

*- the publications await entry in the WoS database, the values take into account indexation in the WoS database

Table 2. Summary of points for journals according to the MNiSW list (after granting of the doctorate, as of 11 November 2018)

No.	Journal	Year of publication	MNiSW points in the year of publication
1	IOP Conf. Series: Materials Science and Engineering (WoS)	2018	15
2	IOP Conf. Series: Materials Science and Engineering (WoS)	2018	15
3	IOP Conf. Series: Materials Science and Engineering (WoS)	2018	0(15)
4	Autostrady	2018	5 (2017)
5	Materials	2018	**35** (2017)
6	MATEC Web of Conferences	2018	0(15)
7	Chapter in a monograph	2018	5
8	Chapter in a monograph	2018	5
9	Autostrady	2017	5
10	Procedia Engineering (WoS), No. Vol. 172	2017	15
11	Drogownictwo	2017	5
12	IOP Conf. Series: Materials Science and Engineering (WoS)	2017	15
13	IOP Conf. Series: Materials Science and Engineering (WoS)	2017	15
14	MATEC Web of Conferences (Gambit – as monograph)	2017	5(15)
15	Drogi i Mosty	2017	11
16	Construction and Building Materials	2017	**40**
17	Drogownictwo	2017	5
18	Road Materials and Pavement Design	2017	**30**
19	Chapter in a monograph (BCRRA)	2017	5
20	Transportation Research Procedia v.14	2016	15
21	Journal of Civil Engineering, Environment and Architecture	2016	9
22	Journal of Civil Engineering, Environment and Architecture	2016	9
23	Chapter in a monograph (Rilem)	2016	5
24	International Journal of Pavement Engineering	2016	**25**
25	Transportation Research Procedia v.14	2016	15
25	Journal of Performance of Constructed Facilities	2016	**25**
26	Journal of Civil Engineering, Environment and Architecture	2016	9
27	Drogownictwo	2015	5
28	Road Materials and Pavement Design	2015	**25**
29	Drogownictwo	2015	5
30	Drogownictwo	2015	5
31	Drogownictwo	2015	5
32	Conference proceedings (WoS)	2014	15
33	Drogownictwo	2014	4
34	Budownictwo i Architektura	2014	3
35	Drogownictwo	2014	4
37	Budownictwo i Architektura	2014	3
38	Inżynieria Morska i Geotechnika	2014	3
39	Logistyka	2014	10
40	Chapter in a monograph (book)	2014	5
41	Chapter in a monograph (book)	2014	5
42	Chapter in a monograph (book)	2014	5
43	Chapter in a monograph (book)	2014	5
44	Chapter in a monograph (book)	2014	5
45	Chapter in a monograph (book)	2014	5
46	Drogownictwo	2012	5
47	Drogownictwo	2012	5
48	Drogownictwo	2011	5
49	Drogownictwo	2011	5
50	Chapter in a monograph (Thessaloniki)	2011	5
51	Drogownictwo	2010	6
52	Inżynieria Morska i Geotechnika	2010	6
53	Autostrady	2010	6
54	Road Materials and Pavement Design	2008	**13**

55	Foundations of Civil and Environmental Engineering	2007	4
56	Drogownictwo	2006	4
57	Conference proceedings (WoS)	2005	15
58	Drogownictwo	2005	4
59	Drogi i Mosty	2004	0
		Total:	543(583)

Please note: entries in bold pertain to points of JCR journals according to the MNiSW list.

8. Summary of didactic and popularising achievements

A detailed list including information on my didactic and popularising achievements is presented in Appendix 4. Table 3 presents a summary of my didactic and popularising activity.

Table 3. Summary of didactic and popularising achievements (according to Appendix 4 – as of 11 November 2018)

Type of achievement	Total number of achievements	Designation according to Appendix 4	Number of achievements after doctorate
Participation in European and other international or national projects	7	III.A	6
Participation in international and national scientific conferences	42	III.B	29
Participation in organising committees of international and national scientific conferences	6	III.C	0
Received awards and distinctions	12	III.D	10
Participation in consortiums and research networks	5	III.E	5
Leadership of projects realised in cooperation with business companies	4	III.F	4
Participation in organising committees of conferences	6	III.G	6
Membership in scientific organisations and societies	6	III.H	5
Didactic achievements	139	III.I	0
Achievements in the field of didactics and popularisation of science: - number of supervised BSc theses (number of supervised BSc candidates) - number of supervised MSc theses (number of supervised MSc candidates)	 68 71	III.J	 68 71
Scientific assistance in doctoral procedures as an auxiliary supervisor	3	III.K	3
National and international internships	4	III.L	4
Completed expert opinions or other commissioned reports	165	III.M	117
Membership in expert teams and scientific contest juries	2	III.N	2
Peer reviews of articles: - for journals from the JCR list - for other journals or on invitation from organisers of international scientific conferences	 7 46	III.P	 7 46

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