20th CONGRESS OF IABSE
New York City 2019

The Evolving Metropolis

REPORT

International Association for Bridge and Structural Engineering IABSE

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Preface

Welcome to the International Association of Bridge and Structural Engineering's (IABSE) ninetieth year! There is no better place to mark this milestone event than in New York City—home to some of the world's most iconic structures. We are meeting for the 20th IABSE Congress to be held September 4 through 6, 2019 under the theme "The Evolving Metropolis."

New York City, created at the turn of the 20th century by the consolidation of the five boroughs of Manhattan, Queens, the Bronx, Staten Island, and Brooklyn, is the definition of a metropolis. Currently, with a population of nearly 8.5 million people, New York City serves as the financial hub of the United States while offering its contributions to American culture and acting as the ambassador to the world by hosting the United Nations.

With the growth of cities around the world, New York City and other urban centers must continue to evolve in order to remain viable places to live and work. This Congress addresses the structural engineering challenges associated with the Evolving Metropolis. More than 400 podium, expert panel, and poster presentations offer engineers from around the world, the opportunity to share ideas, concepts, and lessons learned regarding structural engineering in an urban environment. Attendees will also have the chance to tour some of New York City's famous structures as well as newer, but soon-to-be landmarks.

This Congress also offers the unique prospect of focused study and inquiry as structural engineers gather for two special sessions: 1) The 200-Year Bridge and 2) Tomorrow's Affordable Housing. The one-day housing and two-day bridge sessions—each with a session-ending tour—are intended to generate a work product that will be incorporated into a follow-up IABSE Bulletin, with the session participants serving as the contributing authors. This first-of-its-kind offering at an IABSE event is applying IABSE's mission to further the practice of structural engineering through timely deliverables.

The success of the 2019 IABSE Congress is due to the many dedicated volunteers responsible for both the technical and social aspects of the event. We would like to specifically acknowledge the members of the Scientific Committee and Organizing Committee for their extended efforts as well as the US Group of IABSE, whose members have served vital roles preparing for this Congress.

We welcome you to New York City, an evolving metropolis, and wish you a rewarding time during this 90th year of IABSE.

Jonathan C. McGormley
Chair of the Scientific Committee

Joseph Tortorella
Chair of the Organizing Committee

Statistical survey of existing reinforced and pre-stressed bridge types for the AT-CZ region within the "ATCZ190 SAFEBRIDGE" Project

Eftychia APOSTOLIDI

Dipl. Ing. MSc

University of Natural Resources and Life Sciences (BOKU)

Vienna, Austria
eftychia.apostolidi@boku.ac.at

Specialist in seismic assessment, retrofitting and reliability assessment of existing structures. Actively involved in IABSE TG1.1 and 5.5.

Martina ŠOMODÍKOVÁ

Dr. Ing.

Brno University of Technology

Brno, Czech Republic
somodikova.m@fce.vutbr.cz

Specialist in the field of load bearing capacity and lifetime assessment of existing structures, modeling of degradation processes in concrete.

Alfred STRAUSS

Assoc. Prof.

University of Natural Resources and Life Sciences (BOKU)

Vienna, Austria
alfred.strauss@boku.ac.at

Expert in safety, reliability and performance assessment of engineering structures. Chair of fib Committee 3 and of IABSE TG1.4.

David LEHKÝ

Assoc. Prof.

Brno University of Technology

Brno, Czech Republic
lehky.d@fce.vutbr.cz

Expert in the field of stochastic and reliability analysis of structures, material model parameters identification and artificial neural network.

Drahomír NOVÁK

Prof.

Brno University of Technology

Brno, Czech Republic
novak.d@fce.vutbr.cz

Head of the Institute of Structural Mechanics; Expert in the field of stochastic computational mechanics, reliability of structures, risk engineering.

Contact: eftychia.apostolidi@boku.ac.at

1 Abstract

Advanced modeling of structures using combination of non-linear finite element methods (NLFEM) and reliability analysis is a strong tool for realistic assessment of structures. NLFEM simulation has been recently a well-established approach to the analysis of concrete structures since the response of the structure can be simulated quite realistically. In combination with fully probabilistic approaches, one can consider the randomness of input parameters such as material, technological and environmental characteristics that can have a direct impact on economic aspects during structural lifetime. However, guidelines fully describing NLFEM modeling of structures and safety formats are not available until now. In the framework of the European Project INTERREG AUSTRIA-CZECH REPUBLIC "ATCZ190 SAFEBRIDGE", a number of existing bridges are carefully selected to be studied and modeled with NLFEM on deterministic and stochastic levels based on the upcoming Austrian standard ON B4008-2. The assessment of structures will be described and documented in detail and the results will assist the development of a guideline. This guideline targets to help the engineering community perform accurate NLFEM analysis and to assist the structure's owners to check the accuracy of the assessment process. The current paper focuses on the presentation and discussion of statistical information about road and railway bridges provided by the main bridge operators in both countries. Moreover, the most commonly addressed structural characteristics of bridges within the program region are summarized and the further future steps of the project are briefly described.

Keywords: bridge structures; statistical data; non-linear analysis; reliability; safety

2 Introduction

The existing European road and railway bridge network is being constantly evaluated in terms of road safety, durability and stability. The evaluation targets to support the decision making process on whether structures should be demolished and rebuilt or whether a strengthening/upgrading concept should be developed. Advanced analysis to assess the structural condition of concrete bridges is essential, as the bridge stock is constantly aging, the traffic volume increases and new codes and standards are developed with customized levels of security that have to be met by existing bridges.

The "ATCZ190 SAFEBRIDGE" project, financed by the European Union (INTERREG Austria-Czech Republic), aims to achieve a more realistic analytical modeling of bridges through the consideration of non-linear deterministic and stochastic aspects. The main project partners are the University of Natural Resources and Life Sciences, Institute of Structural Engineering, Vienna, Austria and the Brno University of Technology, Faculty of Civil Engineering, Institute of Structural Mechanics, Brno, Czech Republic. The remaining project consortium consists of strategic partners, which are the main national and county road and railway bridge operators in Austria and the Czech Republic.

The evaluation process in Austria is based on the new standard ON B4008-2 [1] for the assessment of the load bearing capacity of existing road and railway bridges. This standard is currently under publication and it includes four levels of assessment for bridges, with the last two levels involving probabilistic methods as well. Engineering offices specializing in bridge assessment are familiar with the recalculation of the structure for Level 1 (assessment based on current design standards e.g. EN [2], [3], [4]) and Level 2 (assessment using updated information on the load, resistance and safety through the introduction of reduced partial safety factors). However, Level 3 (assessment by probabilistic analysis determining the reliability level of the structure compared to the one of the current design standard) and Level 4 (acceptance of reduced reliability level and corresponding compensatory measurements, such as weight limits, reduced speed, etc.) concern probabilistic aspects that are not so often addressed by engineering offices. In the Czech Republic the situation is very similar and engineering offices mostly assess the load bearing capacity based on Level 1 using current design standards, i.e. deterministic calculation and partial safety factors method.

In the framework of this project, a Guideline will be produced in which the main steps for each of the aforementioned assessment levels will be described in an effort to make the stochastic analysis more approachable to the engineering community and bridge operators. To facilitate this task, five characteristic reinforced and pre-stressed concrete bridges from each country will be selected to serve as case studies. Each case study will be assessed following the process described in the Austrian standard ON B4008-2 [1] and the results will also serve as background for the respective chapters on the Guideline.

In the present paper, the selection process of the bridges to serve as case studies will be presented. The selection concept varies between the two countries, but it is based on statistical data provided by the strategic partners, aiming to focus on characteristic case studies that concern the majority of the structures within the program region. The most commonly addressed features of the bridges in terms of material, cross-section structural type, size and age of bridges will be finally summarized. Finally, the future steps of the project, leading to the aforementioned Guideline, will be briefly presented.

3 Bridge Statistics

The selection of the most appropriate bridges for the current project is based on statistical data about existing bridges within the program region (Figure 1). The program region includes the Austrian states of Vienna and Lower Austria, which share border with the Czech regions of South Moravia, South Bohemia and Vysočina.

As the strategic partners involved in the project are the main national operators for road and railway bridges, they had direct access on data about the full existing bridge stock in Austria and the Czech Republic. The evaluation of this statistical information will end up with the most typical bridge characteristics in the region and will facilitate the choice of the final five case studies in each country to be investigated in detail by the project. The most important information for the selection of characteristic bridges concerned the material and structural type, the size and the age of the bridges.

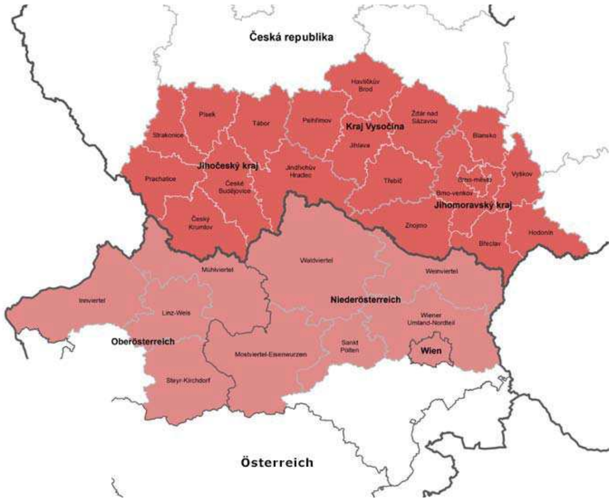


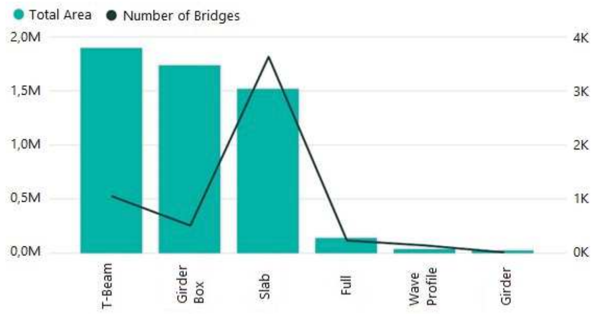
Figure 1. Bridge selection region at the Austrian – Czech border (https://www.at-cz.eu/at)

3.1 Austria

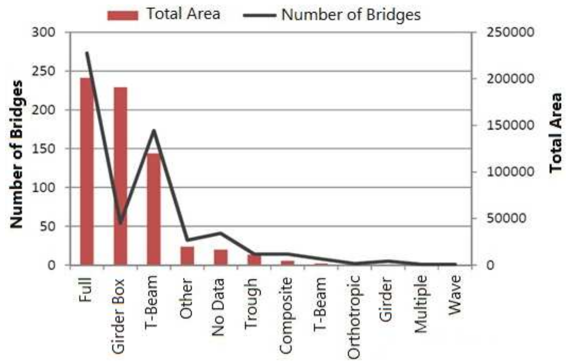
The four main Austrian road and railway bridge operators within the program region (ASFINAG, MA 29, Amt der NÖ Landesregierung and ÖBB) have provided a series of statistical data in terms of bridge number and total bridge area. The characteristics that are evaluated are: (a) the structural type of the cross-section, (b) the material type, (c) span length and (d) year of construction. In the following sub-sections, the diagrams present the statistical data of the aforementioned parameters for each bridge operator.

3.1.1 Structural Type of the Cross-Section

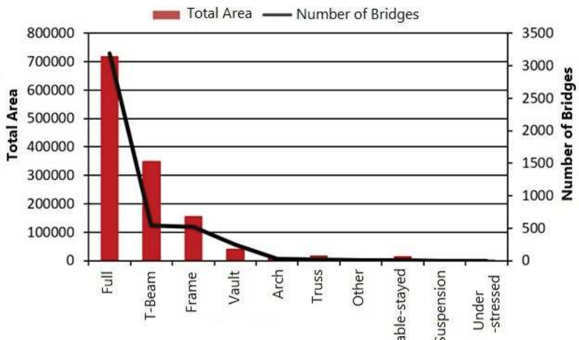
A wide variety in structural type of bridge cross-sections is addressed within the Austrian side of the program region. Figure 2 (a) to (d) presents the statistical data provided by ASFINAG, MA29, Amt der NÖ Landesregierung and ÖBB, respectively, in terms of cross-section structural type of the bridge. The most common cross-section types are full-slab, box girder, T-beam, etc. The statistical data are extracted by individual databases that each bridge operator maintains, therefore several differences on the structural types' names can be observed.



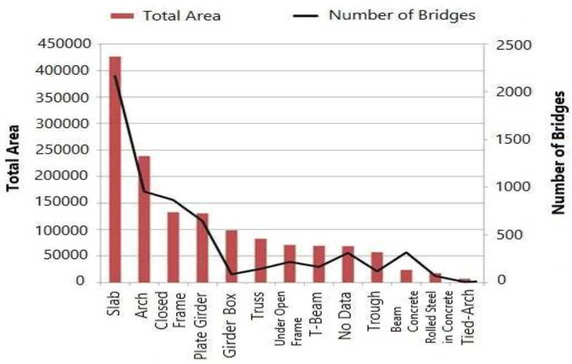
(a) ASFINAG



(b) MA 29



(c) Amt NÖ Landesregierung

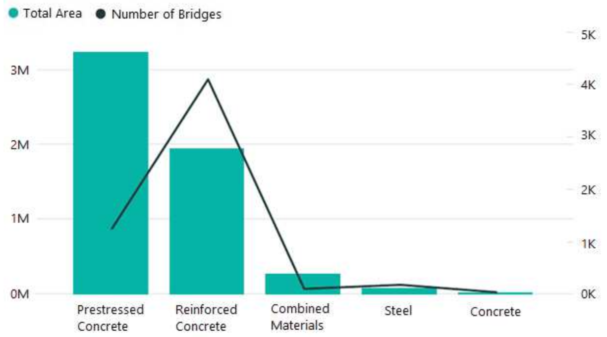


(d) ÖBB

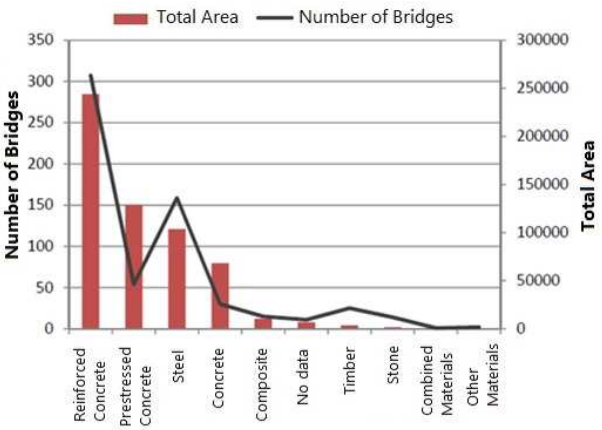
Figure 2. Bridge distribution according to the structural type of the cross-section

3.1.2 Structural Material

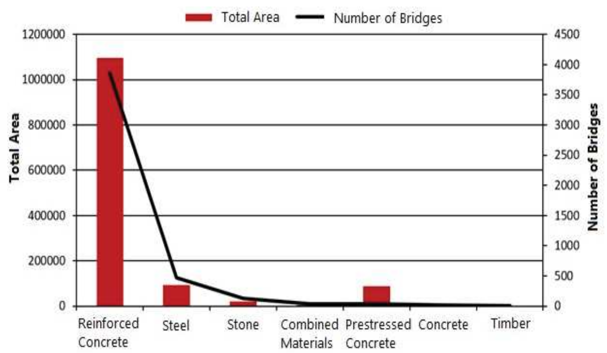
A further important parameter is the type of material used for the bridge construction. Figure 3 summarises all the material types used for railway and road bridges in Austria. It can be noticed that regardless of the bridge operator the most commonly used materials are reinforced and pre-stressed concrete and this concerns both the total area and total number of bridges. Further materials that were used are steel, natural stone, bricks, concrete and combination of materials, but such bridges are not so commonly addressed.



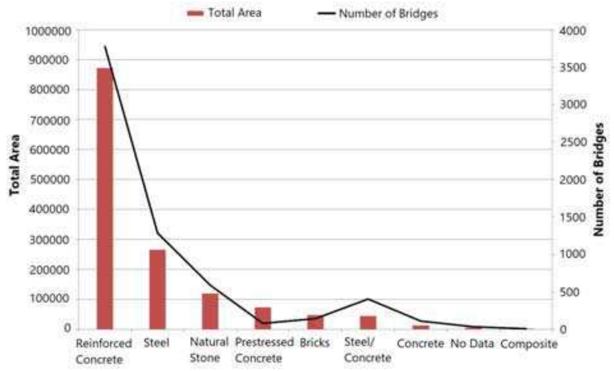
(a) ASFINAG



(b) MA 29



(c) Amt NÖ Landesregierung

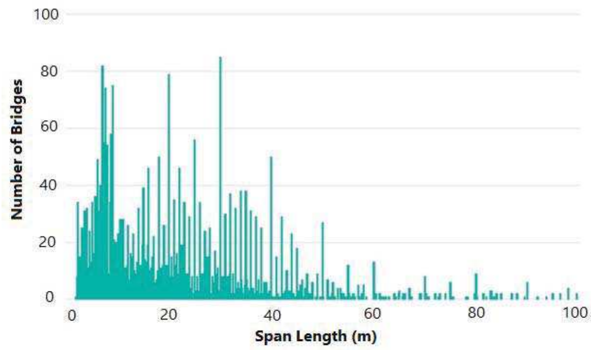


(d) ÖBB

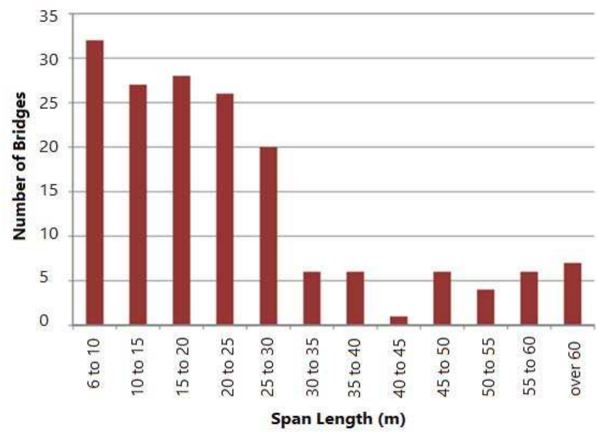
Figure 3. Bridge distribution based on material type

3.1.3 Span Length/Number

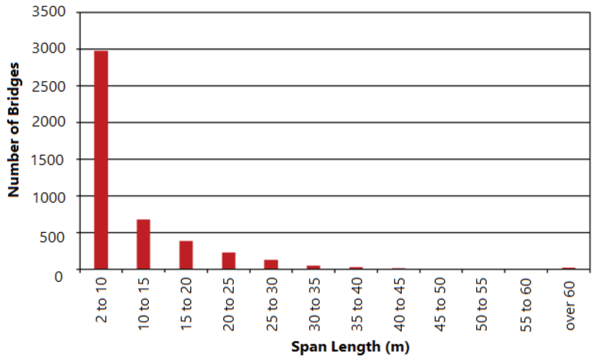
From the provided statistical data, it was observed that the majority of bridges for all bridge operators had one to ten spans, with the longer bridges consisting of more spans being much less. As far as the span length is concerned, the lengths mainly vary between 6 m and 40 m (see Figure 4), although longer and shorter spans can also be addressed in limited number of bridges. The information about the span length concerns only road bridges.



(a) ASFINAG



(b) MA 29

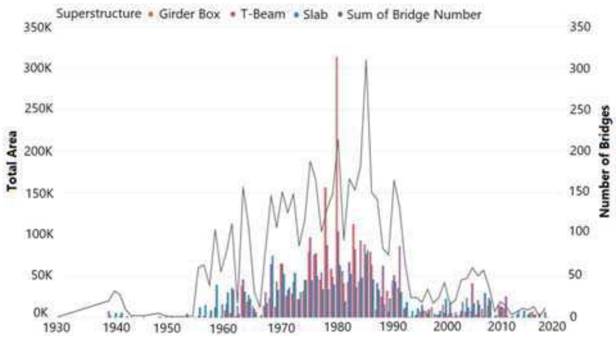


(c) Amt NÖ Landesregierung

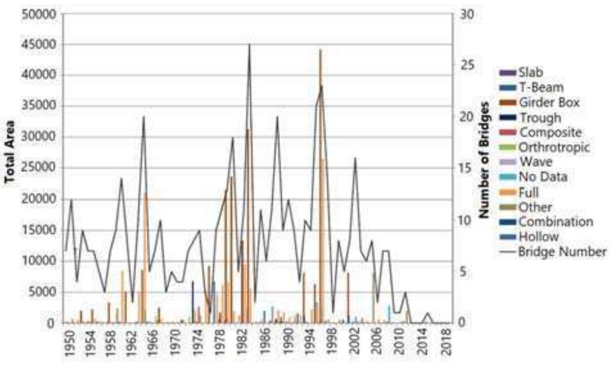
Figure 4. Bridge distribution based on span length

3.1.4 Year of Construction

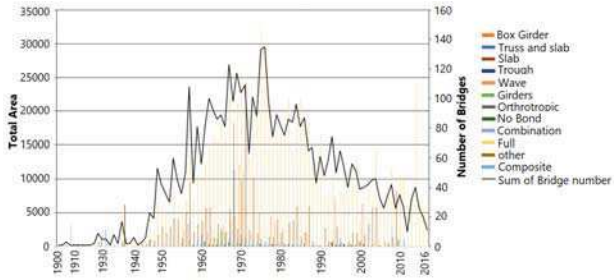
Another parameter of interest is the year of construction of the bridges that is presented for all bridge operators in Figure 5. The provided statistical data from the road bridge operators (ASFINAG, MA29 and Amt NÖ Landesregierung) show that the majority of road bridges in Austria were built between 1965 and 1995. As far as the railway bridges are concerned, the statistics from ÖBB show that, apart from a peak around 1910, most railway bridges were constructed during the period 1975 to 2010. So, the road bridges in Austria are aging significantly and are in need of maintenance.



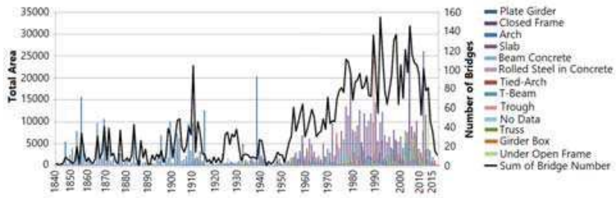
(a*) ASFINAG*



(b) MA29



(c) Amt NÖ Landesregierung



(d) ÖBB

Figure 5. Bridge distribution based on construction year

3.2 Czech Republic

In the Czech Republic, almost all railway bridges (with exception of railway bridges on siding rails) are operated by the Railway Infrastructure Administration, state organization (SŽDC). Data and results of inspections of such bridges are stored in the Bridge Management System. For road bridges the situation about the operation is slightly complicated. Bridges on motorways and 1st class roads are managed by the Road and Motorway Directorate of the Czech Republic (ŘSD ČR), bridges on 2nd and 3rd class roads are owned by regions. Here, statistical data about bridges are available throughout the Czech Republic from the Road Data Bank Department and the National Transport Information Centre. Bridges on local roads are owned by towns and municipalities, or they have private owners. Therefore, in these cases data about bridges are available only for limited number of towns and cities. Bridges in the Czech capital city on the 3rd class roads belong to the Municipal Corporation and are managed by the Technical Administration of roads of the City of Prague.

Series of statistical data provided by the SŽDC (data on 31.12.2017) and ŘSD ČR (data on 01.07.2018) in terms of (a) structural condition (SC), (b) material and age of bridge superstructure, (c) structural type and length are evaluated in the following sub-sections.

3.2.1 Structural Condition

Three classes are defined for the condition of railway bridges; see Figure 6. Classification status of the state of the road bridges involves seven classes that are assigned according to Czech standard ČSN 73 6221 [5]; see Figure 7 ('n' states for undefined).

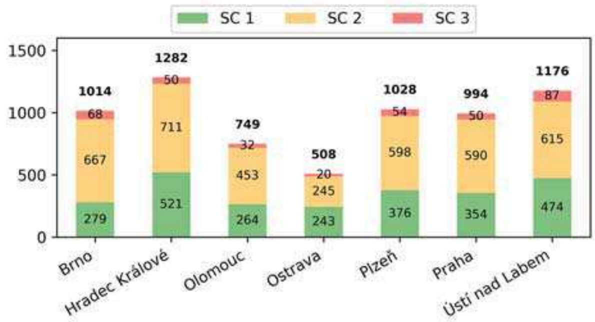


Figure 6. Number of bridges with respect to the SC according to Regional Directorates (SŽDC)

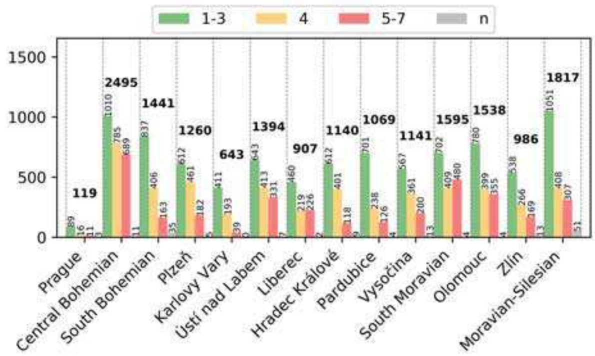


Figure 7. Total number of bridges on motorways and roads considering SC and region (ŘSD ČR)

3.2.2 Structural Material and Age

In terms of management, railway bridges with steel superstructure are the most problematic because of their high number and high average age; see Figure 8 and Figure 9. In case of road bridges, classes 5, 6 and 7 are the most critical, as for these bridges, the load should be significantly reduced to decrease the high risk of serious failure or accident. Data in Figure 10 are valid only for bridges on local roads in Prague, Brno, Plzeň and Karlovy Vary. Within the program region a total of 461 road bridges were built until 1920 on motorways and 1st, 2nd and 3rd class roads; see Figure 11 and Figure 12. These bridges have already reached or exceeded their planned design lifetime and a maintenance or rehabilitation of such bridges is already uneconomic.

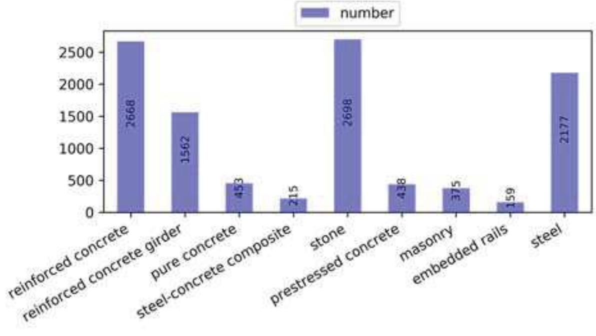


Figure 8. Number of superstructures considering material (SŽDC)

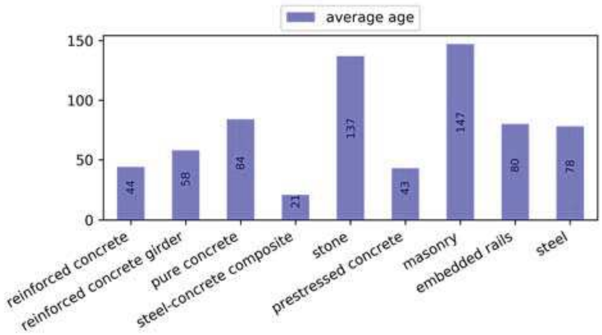


Figure 9. Average age of superstructures considering material (SŽDC)

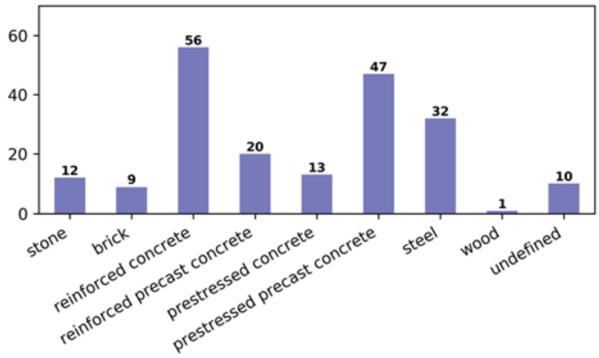


Figure 10. Number of bridges on local roads in SC 5–7 considering material (data adopted from [6])

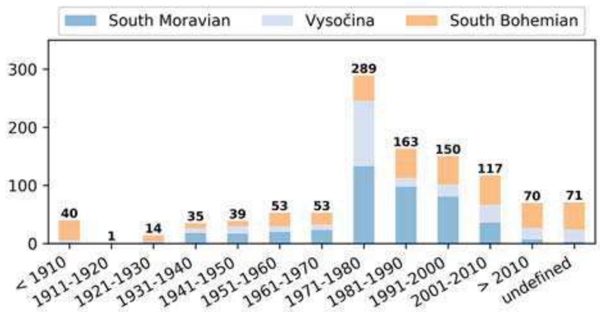


Figure 11. Number of bridges on motorways and 1st class roads considering construction year (ŘSD ČR)

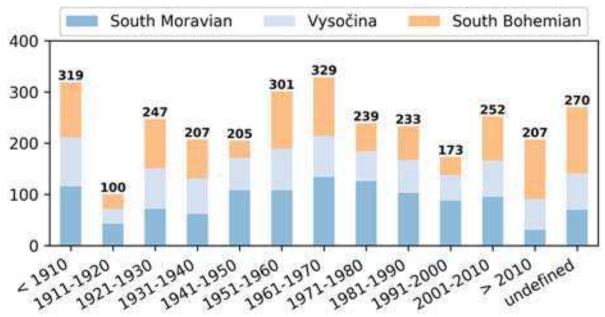


Figure 12. Number of bridges on 2nd and 3rd class roads considering construction year (ŘSD ČR)

3.2.3 Structural Type and Length

The most common types of road bridges' superstructure within the program region are a deck, a vaulted arch and a rigid-frame; see Figure 13 and Figure 14. These types are mostly used in case of small spans bridges (Figure 15).

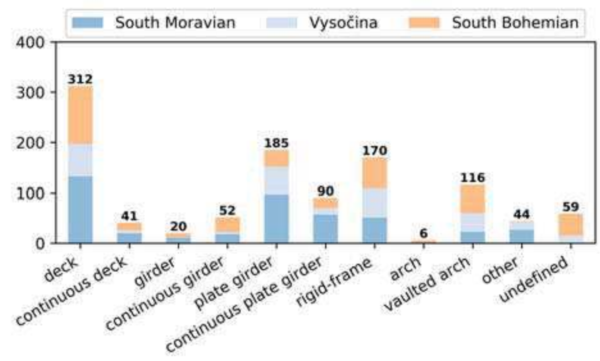


Figure 13. Number of bridges on motorways and 1st class roads considering structural type (ŘSD ČR)

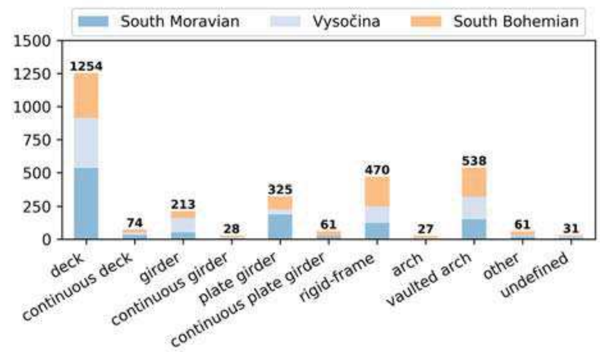


Figure 14. Number of bridges on 2nd and 3rd class roads considering structural type (ŘSD ČR)

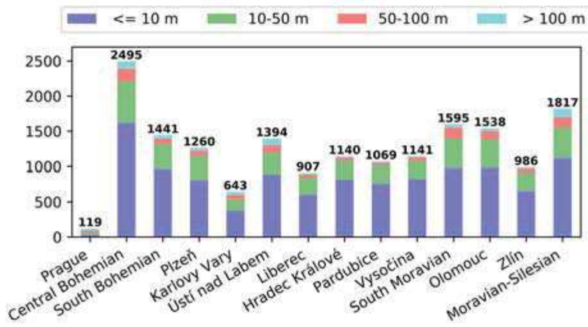


Figure 15. Total number of bridges considering length of bridge superstructure (ŘSD ČR)

4 Discussion and Conclusions

Summarizing the information presented in section 3, concerning the statistical data of bridges in Austria, it was concluded and agreed among the partners and the strategic partners that the bridges to be considered by "ATCZ 190 SAFEBRIDGE" project, should have specific characteristics that could cover a large number of bridges within the program region. So, the selected bridges should be of reinforced or pre-stressed concrete, with a cross-section structural type being slab, T-beam or hollow box. The bridge spans should vary between 1 and 10 and the span length between 6 and 40 meters.

Taking into account the above characteristics, each strategic partner suggested a number of bridges that could be considered by this project as case studies. Finally, all strategic partners agreed on one railway bridge (CS1: slab, 1-span, RC) and four road bridges (CS2: box girder, 9-span, Pre-stressed concrete; CS3: slab, 3-span, RC; CS4: T-Beam, 4-span, RC and CS5: Frame, 1-span, RC) as the final case study (CS) objects.

Concerning the statistical data of bridges in the Czech Republic and based on the requirements and suggestions of Czech strategic partners, one railway bridge and four road slab bridges made of pre-stressed precast girders were selected for case studies. Here, the most common bridge type and the structural condition were the crucial parameters in decision making process.

5 Future Work

As this is an ongoing project (Start: 01/09/2018, End: 31/08/2021), the main outcome will be a Guideline on "Advanced analysis of existing reinforced and pre-stressed concrete bridges: Nonlinearity, reliability, safety formats, life-time aspects". This guideline includes the following parts, based on the analysis of the ten case studies:

- Gathering and updating the existing information: The necessary documents to assess an existing reinforced or pre-stressed bridge are listed, along with state-of-the art inspection and monitoring methods on bridges for the collection of possibly missing information.
- Advanced non-linear deterministic assessment on how to deterministically simulate the most important features of the examined object, in an effort to combine accurate, but rather time efficient modeling methods that could be later adopted by engineering offices. The assessment is performed on Levels 1 and 2 of the ON B 4008-2 [1].
- Advanced non-linear probabilistic assessment, involving stochastic material properties and constitutive models of concrete, steel reinforcement, etc. Stochastic finite element discretization and load models, etc. Probabilistic loading sequence and sensitivity analysis techniques. Probabilistically based partial and global safety factor formats.
- Life cycle assessment models for the prediction of future behavior and remaining life, taking into account environmental factors and other processes that cause deterioration of the structure.
- Performance indicators for the evaluation of the degradation processes, defining the critical indicators that have a significant impact on the remaining future lifetime of bridges.

6 Acknowledgements

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7 References

[1] Austrian Standards. ÖNORM B 4008-2 (2019). Assessment of the Load Bearing Capacity of Existing Structures – Part 2: Bridges (in German).

[2] Austrian Standards. ÖNORM EN 1991-2 (2004). Eurocode 1: Actions on Structures, Part 2: Traffic Loads on Bridges (in German).

[3] Austrian Standards. ÖNORM B4002: 1970 12 0:1 (2009). Road Bridges; General Principles; Design and Construction of Structures (in German).

[4] Austrian Standards. ÖNORM B4003 (1994). Railway and Road Bridges – General Principles for Design and Construction (in German).

[5] ČSN 73 6221 (1996). Inspection of Road Bridges (in Czech).

[6] T. Rotter, M. Teichman, V. Škoch, and J. Volek, "Stav mostů v České republice" [Condition of bridges in the Czech Republic], *Proceedings of 23rd International Symposium Bridges 2018 – Appendix*, pp 1 - 21, 2018 (in Czech).