Editorial

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Current structural engineering is still predominately driven by a spirit to design and build new structures. The structural engineer's vocation is to design and build, even when dealing with existing structures. For many structural engineers, the opinion still prevails that an existing structure has a finite service life of 80 to 100 years and then needs to be replaced by a new structure.

While this spirit was perhaps rational 50 years ago, it is nowadays far away from modern society's demands calling for a focused approach on the built infrastructure. Existing structures are an asset and wealth of a society, and structural engineers are more and more often called upon to maintain and enhance existing structures and infrastructure effectively, within the availability of limited (public) funds, instead of replacing existing structures by new construction.

The first objective of 'engineering of existing structures' is to show that the performance of an existing structure responds to the requirements of modern use with no need for construction intervention. This might seem to be a contradiction for many structural engineers. Only if this first objective cannot be achieved, and when existing structures show damage, are construction interventions required. However, traditional retrofitting techniques are often laboured and invasive, leading to high intervention costs. Modern intervention methods, however, involving targeted use of advanced, high-performance materials can lead in many cases to (cost-) effective engineering solutions with the goal of achieving non-invasive interventions according to the precept 'adding value to existing structures'.

The existing structure exists! Therefore, the verification of structural safety must first rely on in-situ measurements of structural behaviour and action effects, complemented by advanced structural analysis such as refined elastic finite-element (FE) models for structural behaviour under service conditions and fatigue loading, as well as non-linear FE models for the determination of ultimate resistance and deformation capacity of structural members. The approach that needs to be incorporated in the structural engineer's mind may be expressed in the maxim 'getting more out of existing structures'.

If interventions on existing structures are necessary, a targeted use of advanced high-performance materials is often effective in enhancing structural behaviour and resistance. Composite materials, such as fibre-reinforced plastics and ultra-high performance fibre-reinforced cementitious composites and their corresponding technologies, need to be introduced in curricula,

together with advanced technologies in domains such as prestressing or geotechnics.

The ultimate goal of this novel structural engineering methodology devoted to existing structures is thus to limit construction intervention to a strict minimum, while providing the structural performance for long and safe service duration for existing structures with low maintenance needs. While this methodology matches well with principles of sustainability of the built environment, it represents a fundamental paradigm shift for most structural engineers, irrespective of their age, since they are still enlivened mainly by the spirit of new construction.

Currently, the main challenge is that most structural engineers have little or no education in the engineering of existing structures and are hardly even aware of the opportunities available for the effective modern engineering of existing structures. This problematic situation has its roots in conventional civil engineering curricula at most technical universities, which have remained traditional with little significant updating for more than 50 years, in particular regarding the core focus on design of new structures in reinforced concrete, steel and maybe timber. In addition, most design classes in such courses largely comprise the content of current European Standards (EC 1990 to 1999), which reflect the state-of-knowledge from the end of the last century.

Considering this rather bureaucratic and uninspiring design education of structural engineers, it is not surprising that design engineers are nowadays often considered and treated as mere 'code checkers'. They often have a limited understanding of the broader context of their design solutions and insufficient skills to collaborate with other professionals such as architects, building physics engineers and environmental engineers, often coupled with a lack of incentives and motivation, obviously leading to modest fees.

Novel engineering methods and technologies now need to be fully integrated in the education of structural engineers and within the profession, with the goal of adapting and enhancing existing structures and extending their service duration, thereby adding value.

Education of structural engineers would benefit from some fundamental changes. Greater emphasis is needed on principles comprising the essentials of all construction materials in both existing and new structures. The design of new structures needs to be relegated in importance in favour of curricula based explicitly

on the needs of engineering of existing structures, calling for a fundamentally different approach and thinking by the structural engineer. This modern structural engineering approach should also be learned by practising engineers as continuing professional education and development to ‘convert’ the profession to the approach of engineering of existing structures.

Obviously, the basic scientific disciplines of mechanics, strength of materials, probability and reliability theories, and natural sciences (physics, chemistry, biology, geology) still have their place in modern curricula, together with disciplines such as systems engineering, urbanism, economy and law. The examination of existing structures and consequences of intervention decisions related to socio-economic and sustainability criteria are, perhaps, best learned by means of case studies that illustrate both the engineering and non-engineering principles (Brühwiler, 2012).

In addition, knowledge of the history of structures and structural engineering needs to be given greater prominence and treated as a fundamental engineering discipline. History of structures and structural engineering

- deals with history as a basic scientific discipline to study the past of structural engineering and its achievements and relates to the memory and discovery of engineering methods and technology
- comprises construction in a broad sense. It is about the fundamental value and importance of understanding the design and construction of existing structures and their related contexts for the examination of their performance today and with regard to their future use
- is about cultural values inherent in existing structures and structural engineering, thereby creating a better-defined identity for the profession
- develops an understanding of the past as a rich source of inspiration, providing an indispensable basis for the design of new structures
- enhances the general ‘culture’ of structural engineers, providing them the licence to interact with other professionals like architects on equal grounds.

The topic of history of structures is getting increased attention. A working group of the International Association of Bridge and Structural Engineering will soon publish a *Structural Engineering Document on Engineering History and Heritage Structures* (planned for 2018). Various viewpoints and numerous case studies on rehabilitation and modification of bridges and buildings, ranging from ancient to modern structures, from medium to high cultural values, exemplify how requirements of cultural heritage served as an inspiration and basis for better and respectful intervention on the existing structure.

Knowing the past is indispensable for modern structural engineering. Consequently, history of structures and structural engineering is a basic scientific discipline that all modern

structural engineers should master. It should become a fundamental mandatory course in any curriculum to educate civil and structural engineers.

Specific university courses focusing on engineering of existing structures should be based on recent findings from ongoing research and would include, among other topics, methods for accurate determination of in situ structural behaviour with the objective of realistic structural and fatigue safety verification of bridges and other structures, non-destructive testing, using (long-term) structural monitoring and in situ observation as methods to obtain valuable data on actual structural behaviour and actual effects of traffic action, allowing for updating.

Universities are, in principle, well placed to make a difference to this status quo, both through research and teaching. At the Swiss Federal Institute of Technology in Lausanne (EPFL) we undertake a wide range of research projects associated with existing structures (EPFL, 2017a), including the time-dependant reliability and safety of structures, dynamic behaviour and fatigue safety of existing bridges and wind turbine towers, the measurement and monitoring of structural behaviour and action effects (Pousaz, 2012), non-destructive testing methods and the use of ultra-high performance fibre-reinforced cementitious composites for the improvement of existing and new concrete structures.

Many of the skills and techniques developed have been applied in live upgrading projects involving the examination of existing structures (bridges of reinforced concrete, riveted steel and natural stone masonry, as well as buildings) and interventions ensuring their improvement and the preservation of structures of high cultural value, and the aesthetic evaluation of civil engineering heritage structures.

Since 1995, EPFL have offered to both undergraduate and post-graduate students courses on ‘Engineering of existing structures’, ‘Aesthetics and history of structures’ as well as ‘Safety, risk and reliability of structures’ (EPFL, 2017b). While most courses are optional, the students readily understand their importance and consider these classes as being mandatory and profitable for their education. As best illustrated in their project work, the students are highly motivated and learn naturally how to deal with existing structures, using methods that so-called experienced engineers still look upon with reluctance.

Nevertheless, the author considers these successes as being still partial and far below the objectives presented above. This may be explained by the fact that the current curriculum is the result of a common understanding of the faculty of professors in a civil engineering department, consisting of both progressive and conservative opinions.

Today’s structural engineers do not distinguish themselves by innovation and visions, and thus, unfortunately, it will take time until structural engineering curricula at universities will be really modernised

with the goal of engineering of existing structures and following the dictum ‘Learning from the past to design and build the future’.

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