French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of 15 engineering schools/universities. The document also provides information about the supervisor. Please contact the PhD supervisor by email for further information regarding your application.

Supervisor information

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PhD information

Title	Reliability assessment of notched timber components subjected to stochastic mechanical and environmental loading

Main topics regards to CSC list (3 topics at maximum)	Engineering science, Science of materials and new materials
Required skills in science and engineering	fracture mechanics, stochastic computations, numerical methods

Subject description (two pages maximum including biblio)

1. Context and mains issues

Thanks to the advantages provided by its mechanical behavior particularly under extreme loading conditions such as fire and seismic events, in addition to its aesthetic and environmental effects, timber is commonly employed in building and civil engineering structures. By observing historical buildings around the world, it can be seen that timber structures guarantee a long-term service life with a high reliability level. However, timber components exhibit micro-cracks, which can propagate due to fatigue, accidental or creep loads and may be leads to the entire collapse of the structure. A comprehensive survey and analysis [1] of failures observed in 127 timber structures in Sweden have shown that crack initiation and propagation can be considered among the most important failure modes which this type of structures is subjected. Hence, understanding the real physics related to the crack growth process is an important issue when analyzing the integrity of timber structures. In addition, mixed mode crack growth is usually observed in timber elements where initial cracks have random shape and orientation. Commonly, the crack driving forces such as the energy release rate and the stress intensity factors, which allow assessing the behavior of cracked materials, are derived from Path Independent Integral's (PII) based approaches [2]. Despite they have received a growing interest in the last decades; these approaches still suffer from some lacks. Mainly, they are not able to take into account explicitly the effect of environmental loading changes. Indeed, timber is a hygroscopic material whose mechanical behavior is very sensitive to climatic changes such as temperature and moisture variations [3]. For instance, drying process accelerates the crack growth, while wetting process induces the delay of the crack propagation.

Due to its natural origin timber is a heterogeneous material and its mechanical properties exhibit a large dispersion. In addition, mechanical and environmental loading can randomly variate during the timber structure lifetime. Hence, it seems to be essential to evaluate the effect of these sources of variability, firstly on the fracture driving forces and then on the design of timber structures. This issue is commonly addressed using semi-probabilistic approaches provided by the well-known design codes such as Eurocode are which are mainly used in Europe. In a physical point of view these approaches suffer from a lack of consistency. Indeed, the design is performed using characteristic values of the loading parameters and the material properties, obtained through safety factors. Despite these later are continuously updated, they may lead to conservative designs. To cope this problem a fully probabilistic approaches are proposed in the literature [4]. Unfortunately, in the field of timber structures, these approaches receive a growing interest, but their applications still concern simple problems [5]. Indeed, they are based on simple probabilistic models namely random variables not able to model both the space-variate uncertainty of the mechanical properties of the timber and the time-variate uncertainty of the mechanical and the environmental loading. In addition, they are inefficient when the number of uncertain parameters is very large. This problem, called *curse of dimensionality* in the vocabulary of probabilistic analysis, is still a challenging research topic.

2. Research objectives and approach

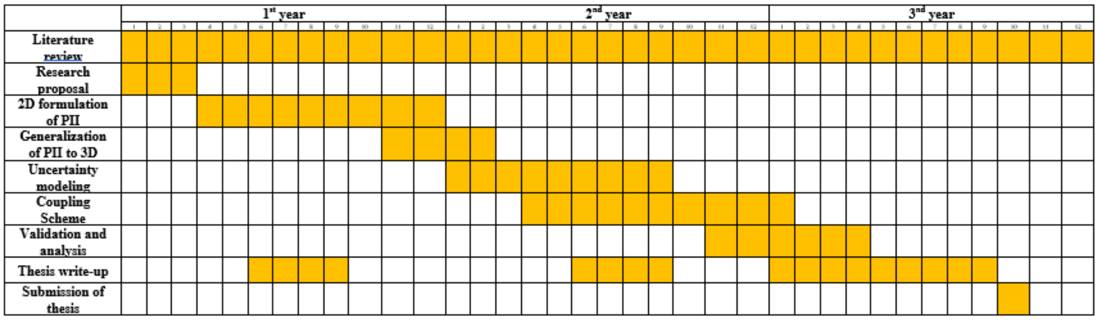
The main objective of the PhD thesis is to develop an original numerical approach able to assess efficiently, on one hand the effect of space-variate uncertainty of mechanical properties of timber material, and on the other hand the effect of time-variate uncertainty of loading conditions especially those related to environmental parameters changes such as temperature and moisture. First, the mathematical formulation of the Path Independent Integral approach [6] will be enhanced to take into account, in explicit manner, the effect of temperature and moisture variation, in addition to the effect of mechanical loading applied in the neighborhood of the crack tip. The accuracy of this new formulation will be assessed in the case of 2D orthotropic notched bodies. The validation will be done through experimental data available in the literature. Then this formulation will be extended to deal with 3D fracture problems and the implemented in finite elements software. The second part of the research project will be dedicated to the development of probabilistic models able to represent the true variability of the uncertain parameters. Advanced stochastic process will be used to model the space-variate and time-variate uncertainties. These models were based on prior knowledges will be updated using Bayesian approach in order to enhance their accuracy. The third part of the thesis will be focused on the development of coupling scheme able to perform efficiently uncertainty propagation through time-consuming mechanical model dealing with notched timber components. This coupling scheme will may be based on metamodeling technics such that Polynomial Chaos Expansion (PCE) [7] and High Dimensional Model Representation (HDMR) [8]. Finally, the developed coupling scheme will be validated firstly on academic problems and then on engineering problems. The obtained results will be compared to those given by traditional design codes.

3. Ph.D. candidate qualifications and skills

The applicant must hold a master’s degree in civil engineering, mechanical engineering, or, alternatively, in applied and computational mathematics. Candidates having a prior knowledge on the fields of fracture mechanics, stochastic computations and numerical methods will be appreciated. In addition, the candidate must be persistent, and having the ability to work independently without constant oversight.

4. Work plan and implications

A detailed work plan for completing the thesis is given in the table below.



5. References

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[7] Ghanem, R. and P. Spanos. Stochastic finite elements - A spectral approach. Springer Verlag 1991. (Reedited by Dover Publications, 2003).

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