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Project Title: Seismic performance and resilience of steel buildings by using high strength steel

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Project Outline:

In this project, it is associated with research themes "*High performance steels and their applications*" and "*Seismic resistant structures in steel construction*". There have been significant developments in steel processing and improvements in industrial processes allowed the achievement of High Strength Steel (HSS) with very attractive properties. However, use of HSS is limited by current Chinese Code for Design of Steel Structures GB 50017 and Code for Seismic Design of Buildings GB 5001. The former limits structural steel grade up to Q420 (with nominal yield strength of 420 MPa). The later requires a higher ductility of steels due to the expectation of inelastic behavior of structural elements and connections under rare earthquakes. Consequently, the necessity of requirements to investigate whether the members fabricated from HSS can be designed according to the existing codes or whether the codes need to be modified to include HSS is highlighted and will be assessed in this research project. Moreover, it is important to determine whether HSS could be used in seismic structures and how to use HSS in seismic resistant structure. In this research project, the key issues associated with the application of HSS in seismic structures will be pointed out and discussed. To begin with, the current state of the art of behavior of HSS and recent research on the seismic behavior of HSS carried out will be reviewed. Through the revisit and reconsideration on the basic level of seismic design philosophy, the design methodologies for application of HSS structures for buildings in seismic zones will be assessed and proposed. This research project can aid the development and application of HSS within steel building under seismic hazards. Additionally, performance and resilience-informed design and assessment of building by using HSS at both component and system levels will be proposed.

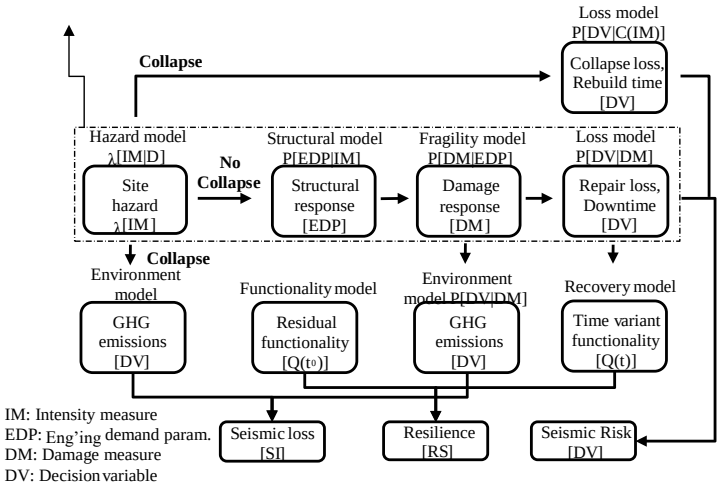
Overall, this research project fits in well within the research themes proposed by CNERC and can aid the development of Theme-based/CRF proposal. Ultimately, the proposed research proposal can facilitate design and construction engineers to work with international engineering and management practice and to enhance international visibility of "Design by Hong Kong and Construct by China". The detailed outline of the research project associated with different task are listed as follows:

Task (1). *Seismic performance assessment of steel buildings using HSS based on nonlinear Finite element modelling*

This task aims at providing the description of the methodology adopted in order to assess the nonlinear behaviour of the investigated steel building using HSS. The focus is on the criteria to be

assumed to investigate the performance objectives by using numerical model. The nonlinear analyses both static and dynamic will be performed by considering the nonlinear behaviour. In general, the nonlinear behaviour is related to two sources: material and geometric nonlinearity. The geometric nonlinearity will be presented in next sub-section. Thus, giving focus on the material nonlinearity, the models may be developed on the basis of two categories, concentrated plasticity models and distributed plasticity models. The numerical models will be developed using the nonlinear finite element-based software.

The nonlinear static "pushover" analysis is an effective tool, not only to assess the inelastic behaviour of a building, but also to reveal weaknesses in the elastic design performed previously in order to ensure the structural integrity. The plastic mechanisms and potential dissipative regions will be obtained for specific load pattern applied to floor level in order to evaluate the overall capacity of structure. In addition to static nonlinear analysis, incremental dynamic analyses (IDAs) will be carried out in order to evaluate the inelastic behaviour of examined frames. The incremental dynamic analyses are a type of dynamic analyses, where the accelerograms are monotonically increased by a nonnegative scalar resulting on a set of accelerograms for a given earthquake. In contrast to nonlinearstatic analysis, these dynamic analyses are more complex and the computational processing time is longer. Both pushover and IDAs will be conducted for the investigated steel building using HSS.



PBEE methodology

Figure 1. Performance-based earthquake engineering

Task (2). *Performance-based earthquake engineering of steel buildings using HSS*

Though the structures subjected to recent seismic events obtained a good behaviour concerning the life safety designed by the current codes, severe damages on structures, as well as economic loss due to lack of use and repair cost are unexpectedly high. Hence, the codes are in a process of fundamental change, and the goal is to reduce these high losses. This issue will be assessed for the steel building by using HSS. In order to solve this issue, performance-based design (PBD), expressed in terms of performance criteria when the structure is subjected to different seismic hazard levels represented by either magnitudes or accelerations, will be developed to aid the design and damage assessment as indicated in Figure 1. The level of ground motion acceleration for each performance level (limit state) will be determined as a function of the return periods, which are related to a certain probability of exceedance during predefined periods of time. In this research,

the seismic performance analysed through static and dynamic nonlinear analyses in the previous task will be compared with three limit states as defined as: Damage Limitation (DL), Significant Damage (SD) and Near Collapse (NC).

Task (3). *Resilience and cost-benefit analysis of steel buildings using HSS*

Within this phase quantitative assessment methodologies will be established to assess the resilience and economic metrics. The PBE proposed in the previous phase has the potential to assess the quantitative sustainability metrics considering performance levels. The consequences associated with the different performance levels include both direct and indirect consequences, and will be assessed quantitively. Finally, building resilience and impact of building performance on the community resilience will be addressed. A building recovery model, within a consistent probabilistic framework, will be established by considering the repair of the damaged building based on performance levels considering physical damage of HSS components and external disruptions (e.g., utility disruption). Specifically, a recovery path will be defined for the performance level considering the repair time and recovery functionality. The externalities and socioeconomic factors, such as the shortage of the materials, on building functionality recovery will be investigated by including the extra repair time to restore the functionality associated with nonstructural components and externalities. System engineering and scheduling methodology inspired by the construction management will be adopted to recovery the building functionality at component and system levels.

The schedule of the proposed research is indicated in the following Table 1.

Table 1. Project work plan for the proposed research

Research Phase	Year											
	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1												
Task 2												
Task 3												

Objectives:

In this research project, the key issues associated with the application of high strength steel (HSS) in seismic resistant structures will be pointed out and discussed. The current state of the art of behavior of HSS and recent research on the seismic behavior of HSS carried out will be reviewed. Through the revisit and reconsideration on the basic level of seismic design philosophy, the design methodologies considering performance and resilience for application of HSS structures for buildings in seismic zones will be proposed. This research project aims to investigate the seismic behaviour of steel buildings using HSS, focusing on the following objectives:

- Validation of the proposed typologies for low/moderate seismicity zones, by advanced numerical simulations;

- Performance and resilience-informed design and assessment of building by using HSS at both component and system levels; and
- Development of design criteria and performance-based design methodology for steel structures using HSS. Criteria for assessment of ultimate building and prediction of the collapse mechanism will also be developed.

Expected deliverables:

In summary, this project is expected to develop a comprehensive framework of development of resilient and seismic resistant steel buildings under a scientific basis and an engineering paradigm. Some publications will also be produced: one journal paper and/or two conference papers.
Postdocs and/or research assistant/associate will be trained during the research time period.