Summary

This PhD thesis deals with the modelling of windblown sand action on civil structures and infrastructures, and the performance assessment of sand mitigation measures. The engineering interest about windblown sand is dictated by the harmful interactions that sand has with a number of structures and infrastructures in arid environments, such as pipelines, industrial facilities, towns, single buildings, farms, roads, and railways. In particular, this represents an emerging issue especially in relation to the design of railway infrastructures crossing deserts. Several failure cases have recently occurred in China and Middle East countries. For example, the Lanzhou-Xinjiang line and the Dammam-Riyadh line have recently suffered derailments, service suspension and loss of capacity due to windblown sand. Other lines are currently in the design, testing and commissioning stages worldwide. However, the design-and-building process suffers significant delays, due to the windblown sand accumulation along the alignment and the retrofitting of the designed railways through sand mitigation measures.

Despite the development of ad-hoc studies for specific projects, systematic and comprehensive problem setting and solving is still missing in the scientific and technical engineering literature. Existing modelling frameworks are limited to the assessment of sand drift far from any built structure. They have been introduced in the past for geomorphology applications. However, these frameworks are purely deterministic despite the inborn variability of the phenomenon. Moreover, albeit with a few remarkable exceptions, the rigorous design and performance assessment of sand mitigation measures are still based on trial and error approach.

This PhD thesis aims at contributing to the proper quantification of windblown sand action on civil structures and infrastructures, and the performance assessment of different kinds of sand mitigation measures. The proposed modelling framework requires a multidisciplinary approach, by making use of notions from mathematics and statistics, physics, geomorphology to structural engineering. The proposed modelling framework is conceived on the basis of the wind engineering analysis chain. Incoming windblown sand is defined in analogy to incoming undisturbed wind. It depends on the environmental characteristics of the construction site, such as the wind field and the sand granulometry. The local windblown sand action is then quantified by taking into account both aerodynamics and morphodynamics of

the affected structure by defining sedimentation coefficients, in analogy to force coefficients for the wind action. Finally, the performance level of the affected structure and the adopted sand mitigation measures can be assessed via a reliability analysis.

The thesis develops according to the above objectives through the following chapters.

The introduction to the study is presented in **Chapter 1**.

Chapter 2 is devoted to the state-of-art and includes a phenomenological analysis of the physical processes, a review concerning the existing semi-empirical models to assess windblown sand transport, a critical review of existing sand mitigation measures for railways, and existing design codes and best practices.

The modelling framework and the study outline are conceptually introduced and justified in **Chapter 3**.

Chapter 4 is devoted to the probabilistic modelling of incoming windblown sand upwind built structures. The outlined probabilistic approach is then applied to different test cases around Arabian Peninsula.

Chapter 5 is devoted to the probabilistic modelling of windblown sand action on structures. First, a phenomenological analysis of windblown sand processes around built structures is provided. The so-called windblown sand limit states are defined in analogy to the common practice in structural engineering. Then, the modelling framework to assess windblown sand action is outlined. Finally, the proposed modelling framework is applied to a case study in order to demonstrate its technical feasibility of the approach and assess the performances of two alternative design solutions against windblown sand.

Finally, conclusions and research perspectives are discussed in **Chapter 6**.