# Life-Cycle Performance and Cost Analysis of Sand Mitigation Measures: Towards an hybrid experimental-computational approach

**Lorenzo Raffaele[1, 3*], Sophia Buckingham[1], Nicolas Coste[2, 3], Gertjan Glabeke[1], Andrea Lo Giudice[2, 3], Jeroen van Beeck[1]**

[1]Environmental and Applied Fluid Dynamics Department
von Karman Institute for Fluid Dynamics
Waterloosesteenweg 72, 1640 Sint-Genesius-Rode, Belgium
{lorenzo.raffaele, sophia.buckingham, glabeke, vanbeeck}@vki.ac.be

[2]Optiflow
Chemin de la Madrague-Ville 160, 13015 Marseille , France
{coste, logiudice}@optiflow.fr

[3]Windblown Sand Modelling and Mitigation joint research group
Italy-France
lorenzo.raffaele@vki.ac.be, {coste, logiudice}@optiflow.fr

## ABSTRACT

Windblown sand hazard affects a number of civil structures and infrastructures in desert and sandy coastal environments, such as pipelines, industrial facilities, towns, single buildings, farms, roads, and railways [1]. The wind flow interacts with surface-mounted obstacles of any kind inducing sand erosion, transport, and sedimentation around them. This can lead to detrimental effects such as the loss of functionality of the endangered structure or infrastructure, e.g. by precluding vehicular and pedestrian traffic, or even danger for users when structural failure is involved. In order to cope with the effects above, the demand for the design of windblown Sand Mitigation Measures (SMMs) has grown in the last decade and it is expected to further increase in the next years [1]. However, with some remarkable exceptions, the rigorous design and performance assessment of SMMs are still missing in the scientific literature and technical practice, and they are still based on trial and error approach. This is mostly due to the multiphysics and multiscale nature of the wind-sand flow which makes the problem only tractable by means of physical experiments or computational simulations. In this study, the authors propose a novel hybrid approach to derive the Life-Cycle Performance (LCP) of SMMs based on the combination of highly reliable Wind-Sand Tunnel Tests (WSTTs) on flat ground conditions, and innovative Wind-Sand Computational Simulations (WSCSs) of the full-scale SMM behaviour. WSTTs are carried out in the Wind Tunnel L-1B of von Karman Institute for Fluid Dynamics to characterize the incoming sand flux in open filed conditions. WSTT measurements allow to properly tune WSCSs. WSCSs are carried out by adopting a Eulerian multiphase 1st order Computational Fluid Dynamics model coupling wind flow aerodynamics and sand erosion, transport, sedimentation and avalanching [2]. LCP is assessed through WSCSs by taking into account the progressive loss of performance of the SMM caused by the gradual accumulation of sand around it. Then, a probabilistic approach to assess windblown sand action and plan sand removal maintenance operation is applied [3]. This allows to account for uncertainties in environmental in-field conditions and in the resulting windblown sand action. Finally, a Life-Cycle Cost Analysis (LCCA) is carried out to assess extra-costs and savings derived from the adoption of SMM with respect to the unmitigated design scenario. The technical feasibility of the approach in an engineering design perspective is demonstrated by discussing its application to a case study dealing with an endangered desert railway.

## References

[1] Bruno L, Horvat M, Raffaele L. Windblown sand along railway infrastructures: a review of challenges and mitigation measures. *J Wind Eng Ind Aerodynam* 2018;177:340–65.
[2] Lo Giudice A, Preziosi L. A fully Eulerian multiphase model of windblown sand coupled with morphodynamic evolution: Erosion, transport, deposition, and avalanching. *Appl Math Model* 2020;79:68-84.
[3] Raffaele L, Bruno L. Windblown sand action on civil structures: Definition and probabilistic modelling. *Eng Struct* 2019;178:88-101.