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Windblown sand mitigation design and experimental testing. The experience of Etihad Rail GCC railway project and the introduction of a new, effective, sand mitigation solution

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SUMMARY:
The first railway project where a systematic scientific approach to sand mitigation has been employed is certainly Etihad Rail Stage 1. In this project, Etihad Rail asked for a full scientific demonstration of the approach to sand mitigation design and deployment, that included geology and geomorphology, computational fluid mechanics (CFD) simulations and extensive experimental testing. A.R.CO.S. Engineering has been contracted since the tender stage in 2010 by the J.V. Saipem, Technimont, Dodsal and then in the construction and validation stage. Through literature studies, extensive CFD simulations, processing of full-scale trial fields data and weather station readings, classical sand mitigation solutions were demonstrated inadequate and a new concept of sand mitigation cross section has been introduced. This cross section has demonstrated a so high efficiency that is nowadays a mandatory standard in all current and new Etihad Rail projects. Since then, A.R.CO.S. Engineering has studied 2000 km of lines in the Arabian Peninsula and has participated to the construction of 500 km of lines and 26 facilities. The abstract illustrates the outcome of this experience and the innovative solution that was developed.

Keywords: windblown sand, mitigation, experimental trial fields

1. INTRODUCTION

Railway construction in desert sandy areas is not new. The end of 19th Century and the beginning of the 20th Century have seen the first lines, the most famous being Hejaz railway, that ran from Damascus to Medina. Built by the Ottoman Empire, had a length of 1320 km and was crossing the border of An-Nafud desert in the Hejaz region.
The early railways in sandy regions were operated with very slow trains and loose time schedule. The issue of sand covering the track was quite common and accepted with all the related inconveniences. Some description of the challenges in construction due to windblown sand is given by (Henry, 1952) for the construction of the line in between Dammam and Riyadh in the Kingdom of Saudi Arabia. Here the approach to sand mitigation was essentially based on the use of fences and on applying "heavy coatings of crude oil" over the sand surface. The problem was recognized being similar to the aeolian transport of snow, that inspired some of the employed solutions.
In 2010, in view of the design of Etihad Rail Stage 1, 2, 3 projects, the company ATKINS performed an extensive review of the existing literature and surveyed sand mitigation systems in railways under operation (ATKINS, 2010, 2012). Numerous computational fluid dynamics were

performed to study possible sand mitigation solutions (ATKINS, 2012). The output of this process was the idea to employ sand mitigation fencing or berms with vegetated upwind surfaces. When Etihad Rail Stage 1 started, the employment of vegetated surfaces was precluded and the recommended sand mitigation systems were the active elements were sand fences, a berm 2 m high with stabilized surfaces and a double berm for higher sand risk areas. These solutions were conceptually recalling what employed in the Dammam-Riyadh line in Saudi Arabia.

2. ETIHAD RAIL STAGE 1 TRIAL FIELDS

The JV Saipem, Technimont, Dodsal was contracted by Etihad Rail to build the Stage 1 line, running from Liwa Oasis to the port of Ruwais in the United Arab Emirates, Figure 1. After the first year of work some trial fields were constructed according to ATKINS studies and recommended cross sections. A.R.CO.S. Engineering was engaged at this point to examine trial field data, propose improvements and finalize the solutions for construction.

Figure 1. ER Stage 1 alignment with monitoring weather stations (left) and satellite view of the trial fields (right).

The full-scale trial fields were located in Habshan and were including a weather station with BSNE sand catchers and anemometers placed at different heights and two orthogonal stretches of track were the simple berm and double berm solutions were under testing, as well as a cross section including a berm, a ditch and a fence, Figure 2. Several anemometers and arrays of BSNE sand catchers were installed in the trial fields. Deep studies were conducted on these trial fields as well as at other locations along the line under construction.

These studies included determination of the vertical wind profile, computational fluid dynamics simulations, development of models to process local monitoring data and onsite rearrangement of the monitoring instrumentation until modelling had achieved scientific repeatability. Sand fluxes were accurately measured by BSNE arrays at several locations inside and outside the mitigated cross sections, as well as at the track platform.


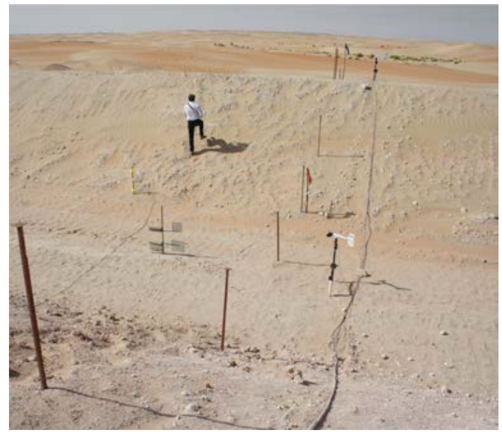

Figure 2. ER Stage 1 trial field view (left) and monitored cross section (right).

3. RESULTS AND DISCUSSION

After one year of weekly data collection and processing, the main result was the observation that, although the berm is a common element used for sand mitigation purpose, its performance its very poor as the incoming sand flux is spread all over the cross section and trapped downwind, with the consequent difficult and costly maintenance. This is due to the "trampoline" effect generated by the berm, projecting sand at considerable height and distance. This phenomenon is quite evident at dune crests, Figure 3.

Figure 3. Windblown sand over a dune crest.

It was then sought, through CFD simulations, a new sand mitigation solution able to: concentrate as much as possible the incoming sand flux at a designed location; keep the sand deposition area the closest to the open field possible; increase the efficiency of the solution; keep the solution earthworks-based in view of maximum durability, sustainability and with minimum environmental impact. The result of this work was the conception and introduction of the Ditch-Berm (DB) cross section, where the external ditch is the active element trapping the incoming sand flux and the berm has the aerodynamic function of promoting sand deposition in the ditch, Figure 4.

The DB system has shown a so high sand mitigation efficiency that is nowadays the mandatory general requirement for all ongoing and new Etihad Rail projects. A typical condition of the track after several years of operation is shown in Figure 5.

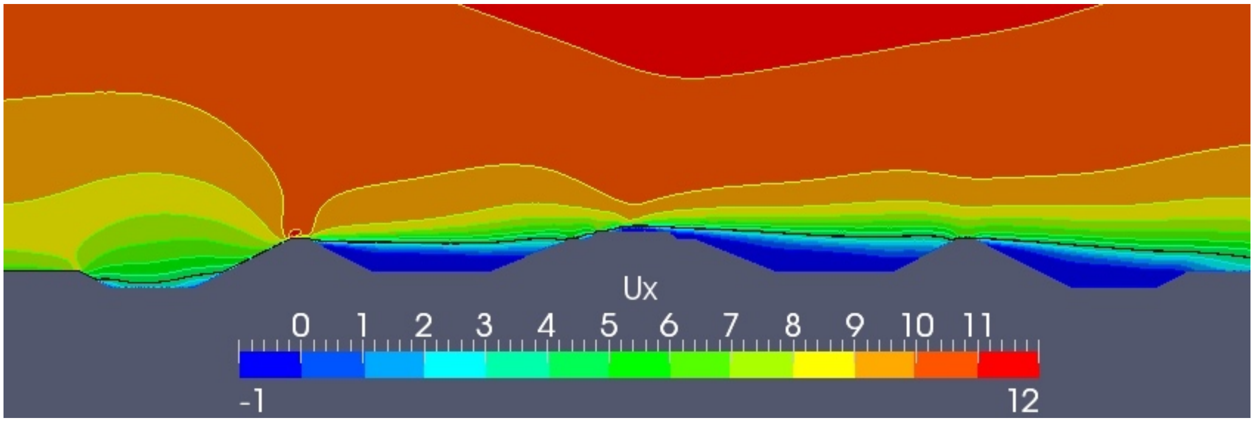

Figure 4.CFD simulation of the DB sand mitigation system.

Figure 5. DB system protecting railway track in UAE.

4. CONCLUSION

A combined numerical and experimental approach allowed to develop the innovative sand mitigation solution for Etihad Rail network. This solution, in operation since 2014, has shown excellent performance, extraordinary low requirement and environmental impact. The approach that allowed A.R.CO.S. to develop this solution is nowadays employed, tuned and improved for new and ongoing projects.

6. REFERENCES

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