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Characteristics of the disastrous wind-sand environment along railways in the Gobi area of Xinjiang, China

Jian-jun Cheng [a, *], Fu-qiang Jiang [b], Chun-xiao Xue [b], Guo-wei Xin [a], Kai-chong Li [b], Yin-hai Yang [b]

[a] College of Water Resources and Architectural Engineering, Shihezi University, Shihezi, Xinjiang 832003, China
[b] Northwest Research Institute Co., Ltd. of China Railway Engineering Corporation, 365 Minzhu East Road, Lanzhou 730000, China

HIGHLIGHTS

- The wind-drift sand that features gravel of large grain size in the Gobi.
- The wind-drift sand that features unsaturation in the Gobi.
- The supply of sand resources controlling the sand emission mechanism in the Gobi.
- The characteristics of wind-drift sand in the Gobi differ from those in desert areas.

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ABSTRACT

Based on detailed long-term data of wind regimes collected from typical ventilation sites along the railways in the Gobi area of Xinjiang, this study systematically analyzes the characteristics of the disastrous wind-sand environment along the railways by combining gradient sand sampling data collected by a wind-drift sand monitoring system and site survey data. Wind direction and speed rose diagrams revealed the prevailing wind direction in each wind area along the railways, and this is the wind direction from which the maximum frequency of sandstorms occurred. Drift potential characteristic parameters (*RDP*, *RDD*) and the direction variability (*RDP*/*DP*) showed that each wind area along the Gobi railway featured a long wind period, with strong power in a single wind direction. The special geological environment of the Gobi determines the wind-drift sand that features gravel of large grain size and unsaturation, which are different from the wind-drift sand in deserts. With increasing wind velocity, the density of the wind-drift sand increased steadily; however, at a certain critical value, the density surged. This study on the wind-sand environment of the Gobi has significance for railway safety. The critical value of wind velocity corresponded to an abrupt increase in the wind-drift sand density and should be taken into account during the planning process of railway safety passage, since this will lead to a decrease in frontal visual distance, and an associated decrease in safety. Additionally, the specific features of wind-drift sand activities, such as the abruptness and higher than usual sand height, should be considered during the process of designing sand-damage-control engineering measures.

1. Introduction

China has the greatest wind-sand disaster distribution along its railway network (Cheng et al., 2010; Wang et al., 2007; Zhang et al., 2010, 2012), particularly in western regions along the Xinjiang railways. Areas of strong winds along Xinjiang railways are mostly covered by the Gobi desert that has extremely poor natural conditions and is sparsely populated. The strong winds are mainly characterized by high velocity, long duration, high seasonality, stable direction and fast velocity variability. Direct destructive effects of the strong winds on the railways result from two sources: firstly, copious windborne particles can break windows, damage the body and even blow over the train; secondly, after the winds pass, huge amounts of deposited particles will cover the tracks, forcing train stoppages (as shown in Fig. 1). Additionally, reduced visibility, caused by windborne dust and particulates, will cause

* Corresponding author.
E-mail address: chengdesign@163.com (J.-j. Cheng).

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Fig. 1. Destructive effects of strong winds on the railways in wind area of Front Hundred Miles of South Xinjiang (A: breaking windows; B: blowing over the train; C: covering the tracks; D: reducing visibility).

train stoppages. Field survey shows that when the wind speed exceeds the range of 26–32 m/s, the sand-driving wind density increases dramatically, and the visibility in the running direction of the train drops abruptly, so it is very dangerous for the train to run under such conditions.

The study of the rules of wind-sand activities in areas from detailed data about the wind regime has resulted in outstanding achievements both in China and other countries. Some international studies have focused on dune movement and aeolian geomorphology evolution, with primarily qualitative conclusions (Bagnold, 1941; Sang-Joon et al., 2004; Li et al., 2004; Jewell et al., 2011; Jabbar Ali Zakeri and Abbasi, 2012; Lee et al., 2002; Zakeri and Abbasi, 2012; Zakeri, 2012; Zakeri et al., 2011), while others focused on the laws of dust transport, with a quantitative approach. In these works, a new parameterization scheme is described, and such a scheme allows the explicit description of the simplified dependence of the vertical dust flux from the wind and the surface conditions (soil type, vegetation, etc.). These can be used in conjunction with air quality models, which is physically consistent and a widely used approach in the quantitative assessment of complex sets of meteorological and land surface interactions (Shao, 2001, 2004; Tegen, 1994). Similarly focused, Chinese studies have primarily concerned wind-sand activities along the Qinghai-Tibet railway due to the construction of the Qinghai-Tibet railway (Cheng et al., 2014; Zhang et al., 2010, 2012; Xu et al., 2006; Zhang et al, 2011). A combination of wind tunnel experiments and field measurements of sandstorms, with wind regime data, have allowed analysis of the wind-sand activities along the Qinghai-Tibet railway that has gradually elucidated rules and characteristics.

However, few studies have assessed the wind-sand activities along the railways in the Gobi area of Xinjiang, China. The characteristics of the peak values of strong wind were analyzed (Yao et al., 2012) while the structural characteristics of wind-drift sand along the Lanzhou-Xinjang railway were preliminarily investigated (Jiang et al., 2010). In order to further understand the rules and characteristics of wind-drift sand along railways in the Gobi area of Xinjiang and provide a basis for the railway department to develop proper sand controlling measures, this study uses detailed wind regime data from this region (from 2005 to 2010) and combines it with wind-drift sand data along lines collected by monitoring systems (from 2007 to 2010), as well as field measurement and survey data. The results further reveal the occurrence mechanism, characteristics and rules of wind-sand disasters along the railway in Gobi area's strong wind zones, and provide a certain basis and reference for the configuration of sand control projects.

2. Environmental characteristics of study area

2.1. Characteristics of regional strong wind environment

The eastern Gobi region of Xinjiang has several distinct ecological and geographic regions that are separated by the Tianshan Mountains running from east to west, which block the cold air flow from the north. As a result, the cold air flow accumulates at the northern foot of the Tianshan Mountains and forms a huge pressure differential with the southern Tu Shan Tuo Basin. Strong winds are created in the north and north-west when the pressure difference reaches a certain degree and cold air rushes out from the pass area along the mountains. Consequent, well-known high wind areas, such as “Yan Dun”, “Hundred Miles”, “Thirty Miles” and “Front Hundred Miles of South Xinjiang” must be traversed by trains to Xinjiang from inland (as shown in Fig. 2).

According to observations, when the wind velocity exceeds 18 m/s (mean velocity over 10 min), wind-sand activities will occur in the Gobi region. Fig. 3 shows the number of days in each month when the wind speed exceeds 18 m/s for each wind area. Across all areas, strong winds were concentrated from April to September, with a peak around June. The most frequent strong winds (>18 m/s) were observed in the “Front Hundred Miles of South Xinjiang” in June with more than 23 days. When the wind velocity exceeds 32 m/s (Fig. 4), it will exert a direct influence on the passage of trains, forcing trains to stop. In addition, such a high wind velocity