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Impact of increasing freight loads on rail substructure from fracking sand transport

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ABSTRACT

The increased use of the hydraulic fracturing technique, used extensively in the USA for oil and natural gas extraction, has significantly expanded the frac sand market and will impact existing freight rail corridors. This growth in the freight rail sector is expected to raise the operation and maintenance costs for the railroads due to the increase in heavy axle loads (HAL), traffic in million gross tons per year (MGT), and fouling from surface spillage.

The impact of HAL on the ballast layer have been studied in some detail; however, it is unknown how infiltration of frac sand into the ballast layer affects the deformational response of the track structure. The purpose of this study was to determine the deformation response due to surface spillage of frac sand into the ballast layer and quantify the effect of moisture in the frac sand-ballast matrix compared to clean ballast.

Three ballast and three frac sand samples were used in this study, of which the following basic properties were characterized: particle-size distribution, mineralogy classification, particle shape, bulk density, void ratio, particle shape, hydraulic conductivity, and soil water characteristic curves. These properties were used to optimize the large-scale cyclic triaxial (LSCT) test method. The results of HAL tests show an increased rate of strain accumulation averaging 0.07%/MGT for every 30-kip car load increase. The results of the surface spillage tests show an average increased rate of strain accumulation averaging 0.05%/MGT, 0.13%/MGT, and 0.31%/MGT for AREMA ballast #24, #4A, and #5 respectively, for a 7% increase in gravimetric water content. These results are crucial for estimating any changes in maintenance cycles and creating life cycle costs estimations. This study will help determine the future of the railway system and how to best engineer solutions for this growing transportation industry.

Introduction

Petroleum industry and hydraulic fracturing

Fossil fuels are vital resources in the American and world economies and are connected to many other industries. The main connection between the oil industry and the frac sand industry has to do with the hydraulic fracturing process. The feasibility and development of directional drilling, specifically horizontal drilling methods, has allowed hydraulic fracturing techniques to become cost effective. A typical hydraulic fracturing treatment costs around $2 million for a 3000-m horizontal well in the Bakken oil basin in Western North Dakota (EERC, 2010). A well of this size is estimated to require 13 million liters of water and 2 million kilograms of sand to produce in the Bakken basin in 2010 (EERC, 2010). This example quantity of sand

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needed per well has been driving an explosive market in the Midwest frac sand industry since the middle to late 2000's.

Frac sand, commonly referred to as silica sand or proppant, is almost entirely silicon dioxide (SiO). Ideal frac sand is well rounded, poorly graded, and, due to being nearly 100% quartz, is a very strong material. Compressive strength between 41,000 and 96,700 kPa is typical for commercial grade frac sand (Wisconsin DNR, 2012) and one dimensional compression of single particle silica sand have shown similar strengths of 29,700–147,300 kPa (Nakata et al., 2001).

Mining and transportation

Frac sand facilities in the Midwest are concentrated in western Wisconsin, northwestern Illinois, southeastern Minnesota, and northeastern Iowa as illustrated in Fig. 1. This region's mining and processing industry produces a majority of frac sand for the US. Of the four states, this study will focus on Wisconsin and Illinois, where the frac sand and ballast samples were obtained.

The surface geology of western Wisconsin has large areas where sand formations are exposed or near the surface. Because of the demand for frac sand, the Wisconsin DNR estimates that there are approximately 60 sand mining, processing plants, and rail load facilities currently operating and at least 30 additional establishments proposed as of January 2012 (Wisconsin DNR, 2012). The increased infrastructure in both extraction, processing and transportation is used to ship increasing amounts of frac sand from Wisconsin to major oil operations across the United States.

The increase in frac sand transportation has the potential to impact the rail systems that support this growing industry in two principal ways. Fracking sand is denser than most other commodities being shipped by rail (textiles, food, coal). This characteristic makes it much easier to meet or exceed rail corridor load capacities. The occurrence of high-quantity, full-capacity trains, which have become more frequent with the frac sand industry growth, introduces potential to increase the rate of degradation to the track structure, specifically the ballast.

Rail substructure

The transportation of fracking sand has potential to be spilt from the cars in small amounts along the route either from wind out of the top of open gondola cars or from vibration out of the drop bottoms in hopper cars. Over time, this buildup of fracking sand in the ballast structure, shown in Fig. 2, can potentially result in increased fouling

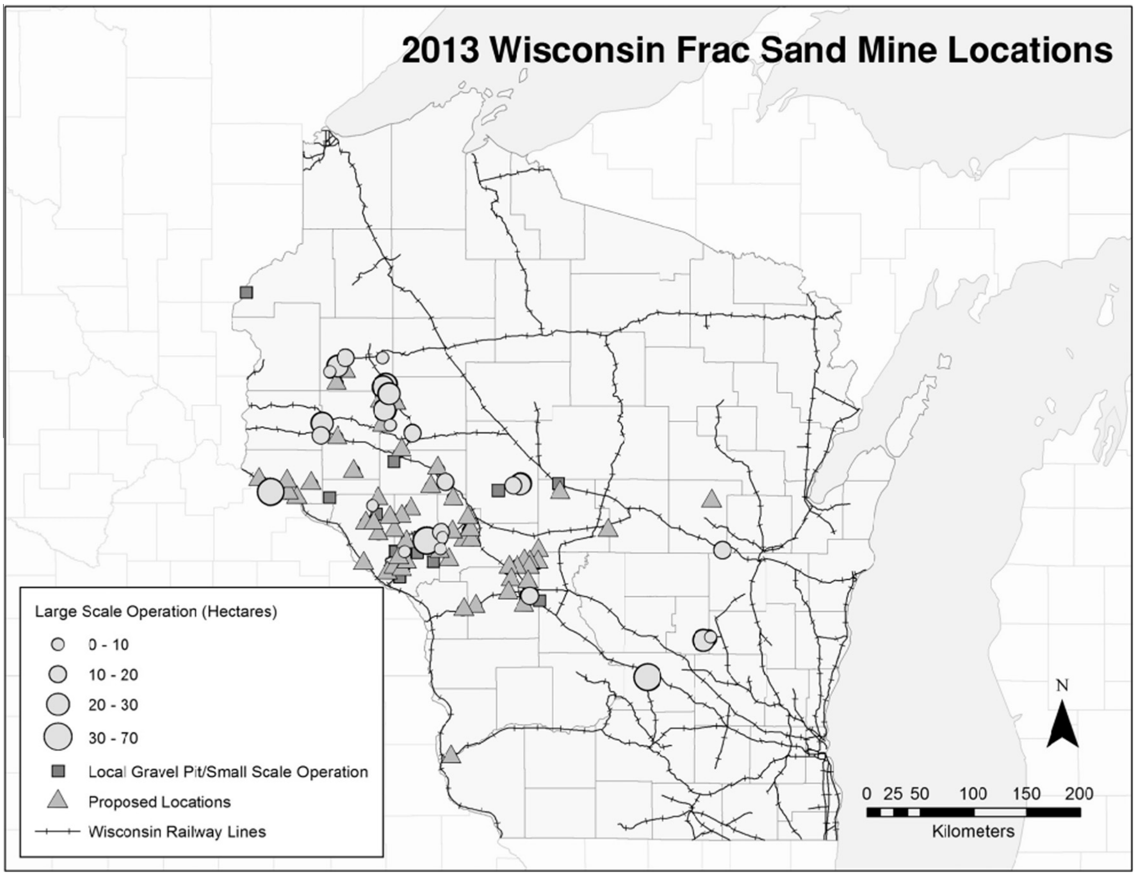

Fig. 1. Frac sand mine locations in relation to rail lines in Wisconsin.