Mitigating localised sand accumulation using wire rope safety barrier

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Key Findings

- Traditional measures to mitigate sand accumulation on the road incur high costs;
- Road safety barriers can contribute to sand accumulation within the carriageway;
- The porosity of barriers can affect the distribution of windblown sand;
- Wire rope barriers offer a potential alternative to mitigate sand accumulation.

Abstract

Sand accumulation on highways is an ongoing problem for road authorities in arid areas across the globe. Typical methods to prevent sand accumulation on highways include landscaping, sand fences and desert resistant vegetation; but these incur high construction and maintenance costs. This paper discusses the impact of different road safety barrier types used in areas prone to sand accumulation and provides a case study of the impact of replacing an existing steel W-beam median barrier with a trial section of wire rope barrier. The trial proved to be successful in mitigating localised sand accumulation and is recommended for consideration in desert environments.

Keywords

Sand Accumulation, Wire Rope Barrier, Median, Highway

Introduction

Road authorities across the globe with desert environments have an ongoing problem of preventing sand being deposited on the highway. As sand is blown across the road, structures such as road safety barriers can be a major cause of localised sand accumulation. Accumulated sand can have a detrimental impact on vehicle handling and adversely affect the safety performance of the barrier.

A Middle East State experiencing frequent sand accumulation on the road has looked at various ways to resolve this problem. Current methods include sand fences, extensive roadside vegetation, and sand clearing operations. This paper proposes an alternative solution that forgoes the need for carriageway sand clearing and closing off lanes to traffic during strong wind periods.

Literature Review

Traditional approaches to mitigate sand accumulation on transport infrastructure such as roads, railways and canals are based on prevention or shielding measures.

Heshmati & Squires (2003) documented two complementary types of measures to address shifting sands. One is to protect existing vegetation on the sand dune or plant trees, shrubs and grasses if there is none or little (these are called biological measures). The other method is to set up physical barriers on sand dunes, such as wire mesh fences, or to cover the surface of the sand dune with straw, clay, tree branches, bamboo, reeds stalks, cobblestone and petroleum chemicals etc. (these are called mechanical measures). Heshmati & Squires suggest that mechanical measures are only effective on their own in the short to medium term and that biological measures will need to be used to complement the mechanical measures for long term effectiveness.

Zhibao et al. (2004) considered methods employed in China to protect highways from sand blowing from the Taklimakan Desert. They suggest that effective measures to control windblown sand include upright clustered reed fences, reed checkerboard barriers, upright reed fences, upright nylon net fences, chemical and clay fixers and artificial vegetation, or a combination of these measures.

Zhang et al. (2010) highlighted that wind-blown sand along the Qinghai-Tibet Railway (opened in 2006) presents a particular challenge due to the low air pressure and air density on the Tibet Plateau. Methods employed to control windblown sand included rocky checkerboard sand barriers, sand-blocking fences, sand-deviating boards and wind-weakening leaf barriers.

Sand Accumulation on an Expressway class road

The road studied is a major expressway in Qatar comprising two 4-lane carriageways, a 3m hard roadside shoulder, 2m hard median strip and a 120 km/h speed limit. Both carriageways are separated by a 16m wide median with two rows of steel W-beam barriers (two-row). Street lighting is provided within the median.

The studied area has an arid desert-like climate and rural feel, characterized by hot summers, scarce rains and warm winters. There are migrating sand dunes close to the expressway and the area typically experiences hot, dry and often windy weather.

Despite the use of sand fences on the north side of the carriageway, sand is able to flow past these fences and onto the road. The sand barriers are approximately 70 to 80m long and positioned diagonally with the road, with the nearest edges being set back approximately 50m from the edge of the road and the furthest edge being 100m away. The barriers are 1.5 to 2.5m high and have a porosity of approximately 0 to 20 percent. Sand regularly builds up immediately beyond the fences during peak sand drift seasons. The two rows of steel W-beam safety barrier on the median further disrupt the flow of sand particles that flow onto the road, which leads to a buildup of sand on the median and within the carriageway. Figure 1 shows an example of heavy sand accumulation after a period of strong wind.

This presents a significant on-going maintenance liability for the road authority to remove sand accumulated within the third and fourth lanes (fast lanes) of the eastbound carriageway during and after periods of strong wind.

KBR (2014) considered options to manage sand accumulation based on a combination of roadside biological and mechanical measures (Figure 2). However, such a suite of mitigation measures was anticipated to incur substantial establishment costs as well as being difficult to maintain in a remote environment.

Figure 3 shows a section of expressway in an urban fringe environment between Doha City and the Hamad International Airport (refer to Figure 6 regarding location). The roadside landscaping implemented in this case is similar to that recommended in Figure 2.

The highway infrastructure and landscaping shown in this photo was implemented as part of a multi-billion dollar roading project to connect Doha with the new airport. Because this site is located on the fringes of urban development, and possibly due to the extensive use of roadside vegetation, it is not typically subject to wind blown sand problems.

However, this level of roadside treatment is not considered feasible for the majority of the remote rural highway network, nor practical in terms of water source and maintenance issues. With the studied road being located in a remote dry desert climate, biological measures requiring substantial water resources were considered difficult to establish and, ultimately, not sustainable. Furthermore, existing methods to prevent sand accumulation along various sections of road (i.e. using sand barrier fences combined with routine maintenance to clear sand around the fences) has not completely prevented the sand from reaching the carriageway.

KBR (2014) also considered the effect of solid versus porous fences on sand accumulation. The report suggested that a porous barrier could potentially improve the distribution of windblown sand across the carriageway (Figure 4). It was therefore hypothesized that a more porous road safety barrier in the median also had the potential to improve the distribution of windblown sand. This led to a trial involving

Figure 1. Heavy sand build up after a period of strong wind

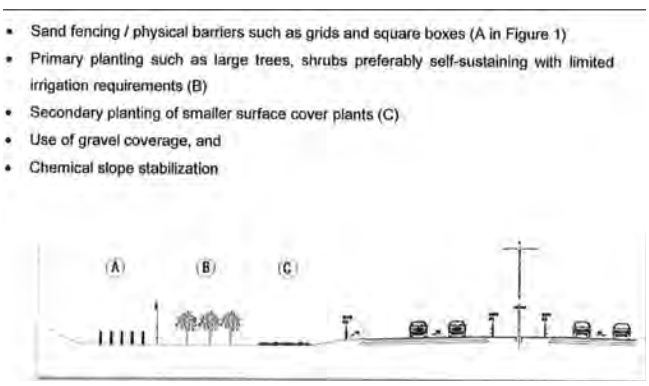


Figure 2. Illustration of roadside mitigation for sand accumulation (KBR, 2014)

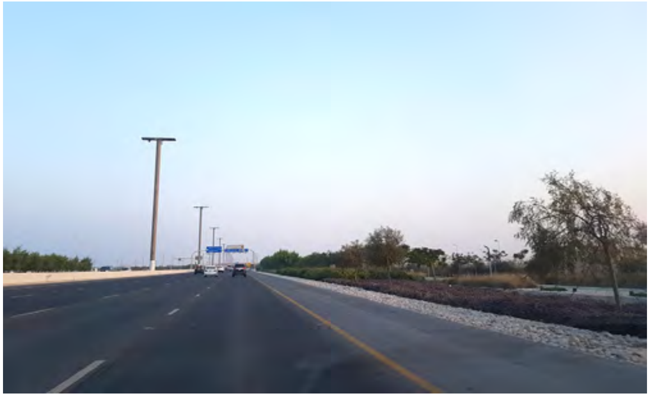


Figure 3. Example of extensive roadside landscaping and vegetation

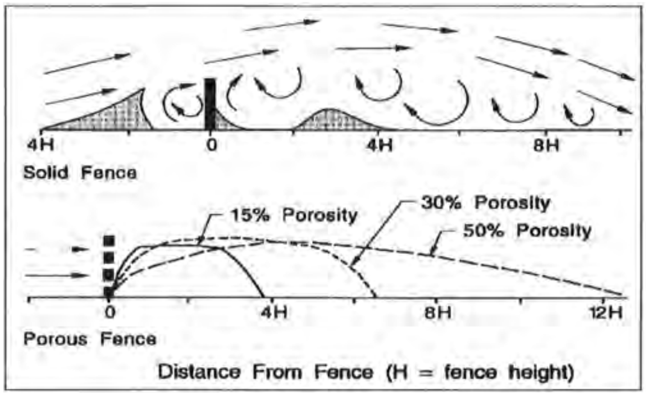


Figure 4. Illustration of sand flows affected by solid and porous fencing or barriers (KBR, 2014)

the replacement of a section of the two-row steel W-beam barriers with wire rope barriers.

Unfounded concerns over wire rope barrier performance in the past have sometimes hindered their liberal adoption by road authorities. There are, however, numerous studies to support the effectiveness of wire rope safety barriers. Three studies worth mentioning include Ohio's Department of Transport (2005), WSDOT (2013) and Cooner. S. et al (2009). These reports support the substantial body of evidence and research which suggests that wire rope safety barriers reduce the rate and severity of vehicle collisions and are more forgiving than other barrier types.

Whilst there is a common perception that wire rope safety barriers are especially hazardous for motorcyclists, this is not supported by research. Melendy, L. et al. (2006) found that most riders are separated from their motorcycles and are sliding on the ground when they contact a barrier. The safety risk motorcyclists experience in this situation, i.e. the posts, is similar for both wire rope barriers and steel W-beam barriers. Daniello, A. et al. (2011) found no appreciable difference in fatal and severe injuries when comparing wire rope safety barriers and steel W-beam barriers. While concrete barriers performed better for a sliding motorcyclist, because there are no posts, none of the barriers protect an upright motorcyclist from being thrown over the top and into a roadside hazard or opposing traffic. It should be noted that concrete barriers would not be a suitable solution in this particular case because they are particularly prone to sand accumulation. Figure 5 illustrates the extent of sand accumulation caused by a concrete barrier installed at a weigh station located on the same road as the trial site.

In summary, it can be stated that wire rope safety barriers represent an effective road safety solution and are the most forgiving type of barrier with the lowest overall ratio of deaths and serious injuries from barrier collisions. It was also hypothesised that a more porous wire rope barrier system had the potential to mitigate the accumulation of windblown sand by allowing sand to pass freely through the barrier.

Installation and Observations

A trial was undertaken on a remote section of Salwa Road, approximately 80 kilometres west of Doha, Qatar, to replace sections of existing steel W-beam median barriers (Type N2 under the European EN1317 specification) with a wire rope safety barrier system. The wire rope safety barrier comprised a four-strand high tension system to Test Level 4 under the US NCHRP-350 specification (Make: Armorwire DSR galvanized, grade 1320 RHL). Figure 6 shows the general location of the trial site, noting the remoteness from any developed areas. Figure 7 provides the general climatic conditions of the studied area and Figure 8 shows the installed wire rope barriers on the median.

The wire rope safety barriers were installed between March and August 2015, with the westbound wire rope safety barrier being completed on 31 May 2015. There was a period of evaluation with one row of wire rope barrier and one row of steel W-beam barrier (refer to Configuration 2 in Figure 9) before the eastbound wire rope safety barrier was finally completed on 10 August 2015.

Eight site visits were carried out between June 2015 and March 2016 during and following strong wind periods to identify the extent of sand accumulation on the carriageway for each of the three barrier configurations: 1) two-row W-beam, 2) split wire rope / W-beam, and 3) two-row wire rope.

The site visits were undertaken at least 6 hours after forecast wind speeds above 20 km/h were experienced (assessed using local weather forecasting information on projected wind speeds) and at various time periods after the start of the strong wind periods so that sand piles were able to form over different durations.

Figure 9 provides the general layout and the sequence of barrier types installed:

Prior to the trial, with the existing two-row W-beam median barriers (Configuration 1), sand would accumulate in significant deposits on the hard median strip and within the third and fourth (fast) lanes. Figure 10 provides a typical

Figure 5. Example of sand accumulation associated with a concrete barrier

Figure 6. Location map of observed road (Salwa Road, Qatar)

example of sand accumulation with the two-row W-beam barriers. During, and following, strong wind periods the third and fourth (fast) lanes of the eastbound carriageway would be closed to live traffic using traffic management measures.

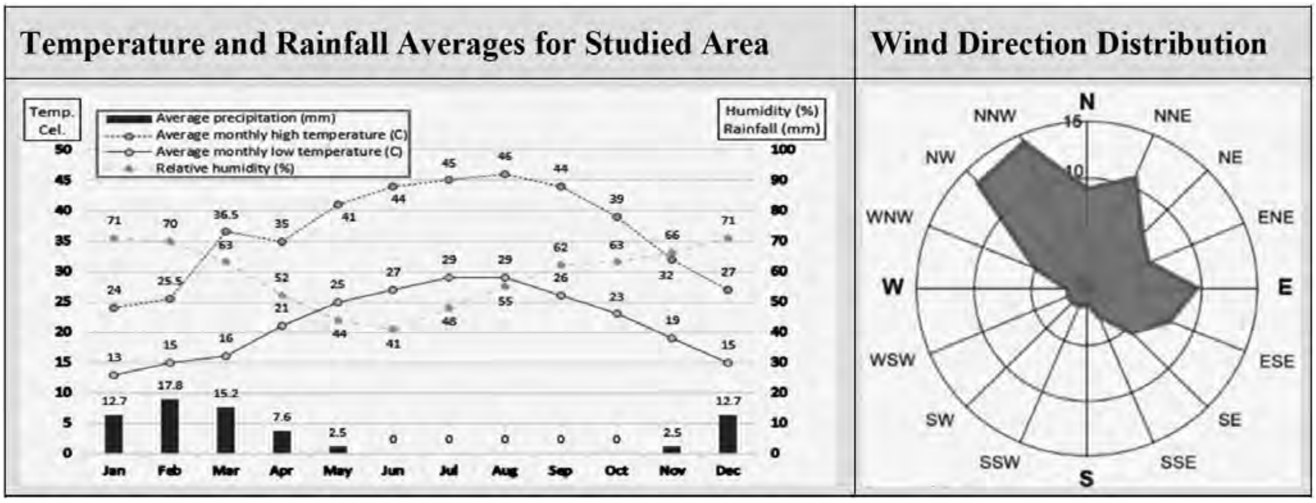
When the first wire rope barrier was installed on the westbound carriageway (Configuration 2: split wire rope / W-beam barriers), there was a noticeable effect of sand being deposited further across the eastbound carriageway in the second lane. Figure 11 shows the shift in sand accumulation patterns under Configuration 2 with the split wire rope / W-beam barriers.

This situation required even further lane closures with sand accumulating across into the second lane. This result also highlights the need to carefully consider the potential impact of road safety barrier location and the sequencing of barrier types on potentially adverse sand accumulation patterns.

Once the second row of wire rope safety barrier was installed on the eastbound carriageway (Configuration 3: two-row wire rope), it was clear to see that sand flows were less obstructed by the barriers. Figure 12 shows a typical observation where sand is relatively free to flow across the road without resulting in significant deposits.

A summary of the site observations for the three different median barrier configurations is presented in Table 1.

Sand accumulation records in Table 1 indicate where stationary sand piles had developed to the point where they were considered a potential hazard to vehicle handling and / or warranted lane closure. The table summarises the sand accumulation patterns that were observed for



Information Sources: www.windfinder.com, www.weather.com, information obtained in August 2017. Note: Wind Direction Distribution speed in knot

Figure 7. General climatic conditions of study area

Figure 8. Wire rope barrier installation (August 2015)

the three different median barrier configurations. These shifts in sand accumulation patterns were clearly observed from the formal site investigations as well as being further supported anecdotally through ongoing correspondence with Contractors before, during and after installation works.

There were no significant sand deposits observed under the two-row wire rope safety barrier configuration as a result of wind speeds of 20 km/h or greater. Moreover, the wire rope safety barrier's vertical surface area is estimated to have a high porosity value of over 90%, compared to approximately 60% for a W-beam barrier (estimated from NZTA, 2017), which allows the windblown sand to pass through and

Figure 10. Sand accumulation with existing two-row steel W-beam barriers

clear the wide carriageway on the downwind side of the median. This is compatible with the anticipated sand flow and deposits diagram shown above in Figure 4 and supports the hypothesis that a more porous wire rope barrier system improves the distribution of windblown sand. The results also suggest that wire rope safety barriers in both directions are needed within the median for the sand to flow past the carriageway completely.

Whilst not the main objective of the study, observations during construction identified adverse sand accumulation patterns with the split wire rope / W-beam barrier configuration. The two split barrier configurations noted in

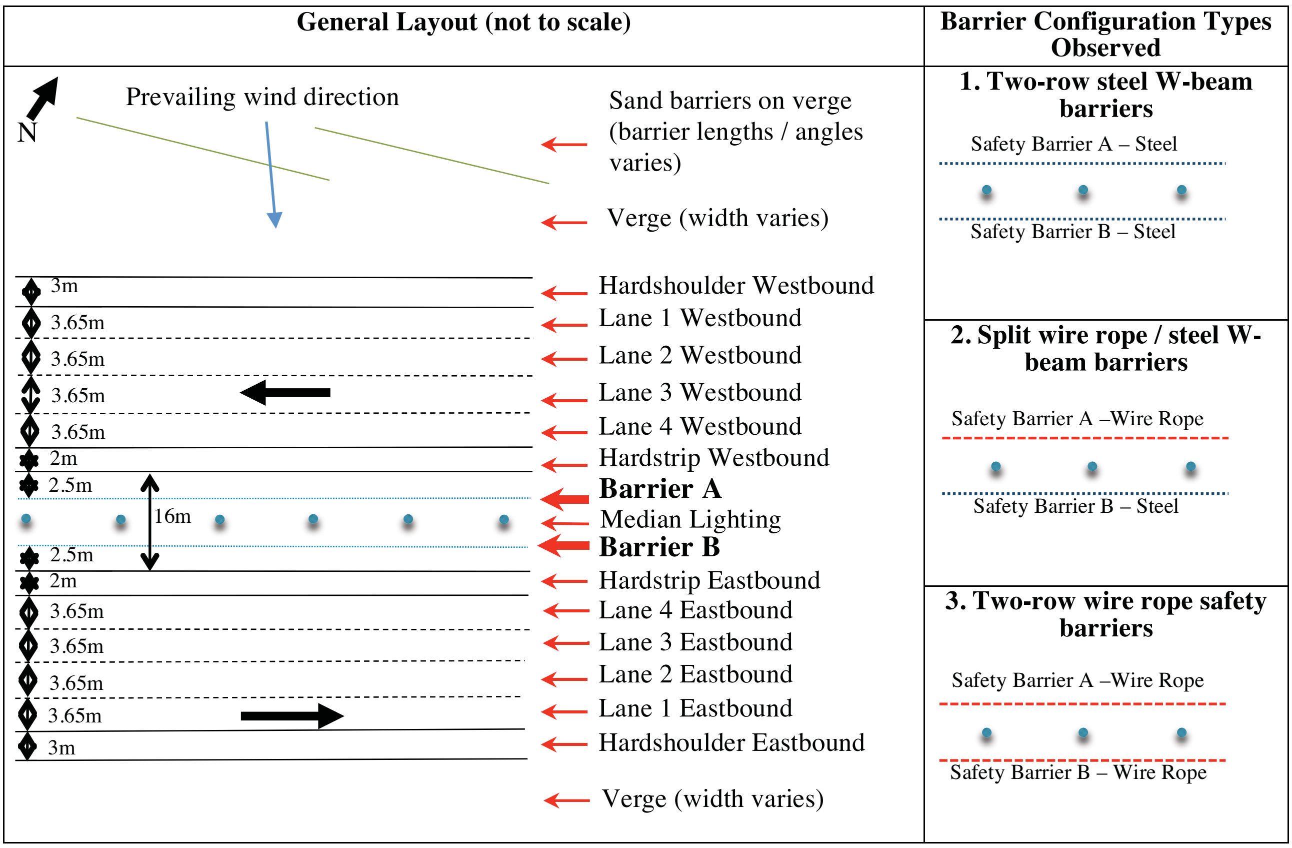


Figure 9. Indicative layouts of median barrier configurations observed

Figure 11. Sand accumulation with a split wire rope and steel W-beam barrier configuration

Figure 12. No sand accumulation with two-row wire rope barriers

Table 1. Sand accumulation observation results

Date/Time of Visit	Wind Direction	Wind Speed (km/h)	Temp. (degrees Celsius)	Barrier Configuration	Sand Accumulation Position on East-bound Carriageway				
					Hard strip	4th Lane	3rd Lane	2nd Lane	1st lane
09.06.15 12PM	South	27	41	Two-row W-Beam	■	■			
09.06.15 12PM	South	27	41	Split W-Beam / Wire Rope			■	■	
22.06.15 9AM	South-South-East	45	42	Two-row W-Beam	■	■			
22.06.15 9AM	South-South-East	45	42	Split W-Beam / Wire Rope	■	■	■	■	
09.07.15 10AM	South-South-East	27	38	Two-row W-Beam	■	■	■		
11.10.15 12PM	South-East-South	35	37	Two-row W-Beam	■	■			
11.10.15 12PM	South-East-South	35	37	Two-row Wire Rope					
07.12.15 9AM	South-East	47	17	Two-row W-Beam	■	■	■		
07.12.15 9AM	South-East	47	17	Two-row Wire Rope					
03.01.16 11AM	South-East-South	27	20	Two-row W-Beam	■	■	■		
03.01.16 11AM	South-East-South	27	20	Two-row Wire Rope					
14.02.16 2PM	South	20	21	Two-row W-Beam	■	■			
14.02.16 2PM	South	20	21	Two-row Wire Rope					
24.03.16 8AM	South-South-East	24	19	Two-row W-Beam	■	■	■		
24.03.16 8AM	South-South-East	24	19	Two-row Wire Rope					

Note: the wire rope installation on the eastbound carriageway (final installation) was over a longer length than the westbound carriageway (first installation), which is why it was possible to observe different combinations during the same site visit.

Table 1 were recorded immediately adjacent to the two-row W-beam sections during a pass through the site while construction was underway. The shifting of sand from lanes 3 and 4 into lane 2 with the split configuration underlines a further important consideration to note when locating and combining various barrier systems. It also highlights the potential for shifting of sand patterns during construction as part of any safety barrier retrofit works.

Two other substantial lengths of highway in Qatar that have been treated with wire rope median barriers include the Lusail-Salwa Temporary Truck Route and Ras Laffan Road (Figure 6), which have been operational since Winter 2014 and Autumn 2015 respectively. Both highways comprise two lanes in each direction with a wide central median.

Correspondence with the Public Works Authority Road Maintenance Department suggests, anecdotally, that there have been no instances of substantial sand accumulation on these routes that required closing of running lanes or clearance work.

Conclusions

Sand accumulation on highways is an ongoing problem for road authorities across the globe, particularly in environments with desert landscapes such as Africa, the Middle East and Asia. Sand accumulated on the highway can lead to serious loss-of-control and run-off-road crashes. Typical methods to prevent sand accumulation on highways include landscaping, sand fences and desert resistant vegetation. Such measures can potentially generate significant establishment and maintenance costs and challenges, particularly in remote locations. Even with these measures in place, sand may continue to blow onto and across the road.

As sand is blown across the road, roadside structures such as road safety barriers can be a major cause of localised sand accumulation. This not only has the potential to adversely affect vehicle handling but could also reduce the safety performance of the barrier.

A two-row wire rope median safety barrier arrangement was trialed to replace the existing steel W-beam barriers on an expressway class road passing through a dry desert environment and the effects were monitored during strong wind periods. The results indicated that the wire rope safety barriers allowed sand to flow almost unimpeded across the highway with no sand accumulation observed within the carriageway. Whereas, median barrier configurations that incorporated W-beam barriers resulted in the interruption of sand flow with significant deposits of sand accumulating within the carriageway.

There is a substantial body of evidence and research suggesting that wire rope safety barriers reduce the rate and severity of vehicle collisions and are more forgiving than other barrier types. This study suggests that wire rope safety barriers also offer significant potential as an alternative or supplementary measure to help mitigate localised sand accumulation. It is recommended that road authorities consider this wire rope treatment when conventional methods are not totally successful, or a comprehensive roadside landscaping treatment is not feasible.

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