

Wire Rope Barrier Monitoring System (Load cell communication) – An overview

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Abstract

Application of median wire rope safety barrier overseas had resulted in a reported 80% reduction in cross centre line casualty crashes. The key objective of the treatment is to prevent fatalities and serious injuries as a result of head-on crashes and other cross centre line crashes, consistent with South Australia’s Road Safety Strategy – Towards Zero Together and Safe System principles. However, use of flexible barrier in a narrow median raises issues with maintenance monitoring and safety of operational staff when a repair is required.

Victor Harbor Road was chosen for median wire rope barrier installation as it had experienced a number of serious and fatal crashes due to vehicles crossing the centre line. This was the first targeted application of installing median wire rope safety barrier on a four-lane (2+2) 100 km/h road in South Australia. This project involved the installation of 2.3 km of wire rope safety barrier along the centre of the Willunga Hill four-lane carriageway section of Victor Harbor Road.

Maintenance requirements were assessed from a routine visual and structural inspection viewpoint to ensure the treatment remains effective. Due to the traffic flow and speed environment it was decided to supplement the median wire rope barrier with an innovative remote tension and impact monitoring system.

This real-time notification feature is an Australian first and provides improved safety through minimising physical site visits, as well as improved response times to a potential failure of the barrier in the event of heavy impact.

Keywords

Safer Roads, Safe System, Rural Roads, Median Wire Rope, Load cell, Monitoring System

Introduction

Run-off road and head-on type crashes represent the largest single source of serious road trauma. In recent years, runoff road and head-on type crashes accounted for six to seven of every ten fatalities on South Australian Roads. In the 5-year period 2007-2011 run off road crashes (hit fixed object, rollover, left road out of control) and head-on crashes accounted for 73% of the total serious and fatal casualty crashes in rural South Australia. (DPTI, 2013)

In 2012, 66% of all fatalities in South Australia occurred in rural areas*. This is slightly higher than the 2007-2011 average of 61% of fatalities occurring in rural areas. A less frequent, yet very severe crash type, especially in high speed settings, is the head-on crash. In rural areas, head-on crashes on undivided roads are a serious concern. In 2012, there were 13

* About 1/4 of the population live in rural areas.

head-on fatal crashes in rural areas and 11 cross-centerline crashes out of the total of 57 rural fatal crashes. (DPTI, 2013)

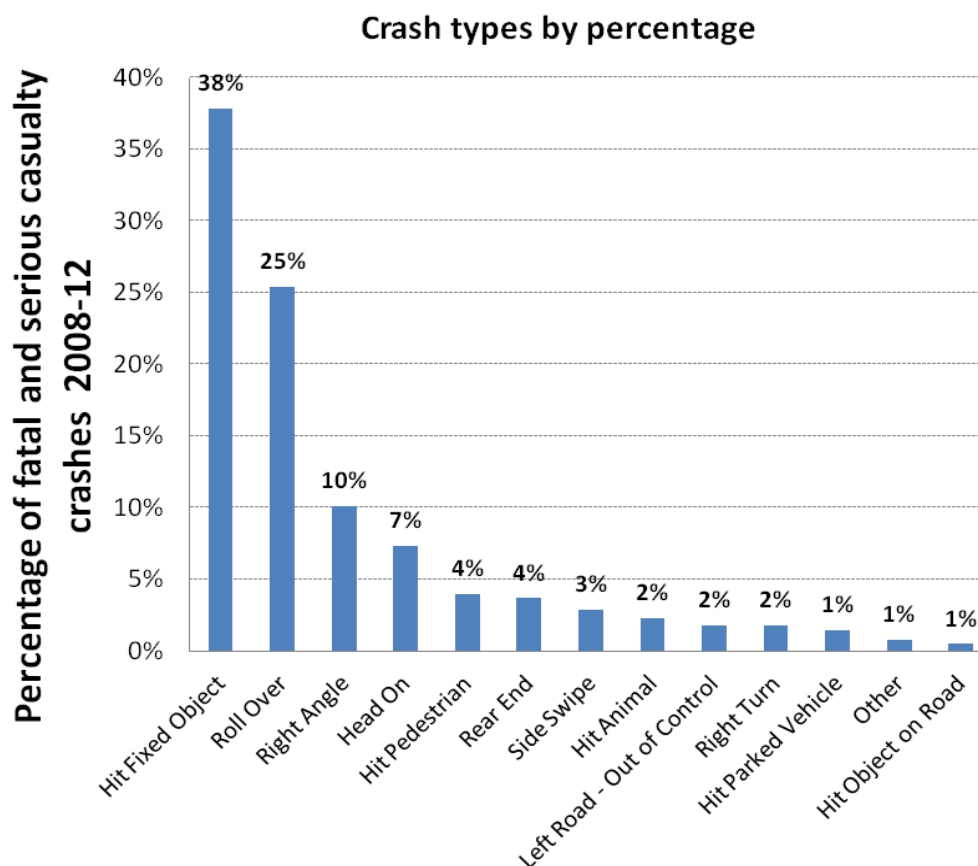


Figure 1

Percentages of fatal and serious casualty crash types on rural roads in South Australia 2008-2012, DPTI (2013)

A number of studies conducted in recent years have involved analyses of these crash problems and investigation of possible countermeasures. Among the most promising solutions is the use of wire rope barrier erected over a length of roadway. The main barrier implementation scenarios are:

- In existing medians to separate opposing directions of high-speed traffic, and to prevent vehicle rollover and crashes into rigid objects within medians.
- Along the left side of the carriageway, for each direction of travel, to prevent collisions with roadside trees and fixed objects.
- As mid-barriers along single-carriageway roads mainly to separate opposing directions of high speed traffic, but to also prevent vehicle crossover to other side of the road and roadside.

Project Background

The Centre for Automotive Safety Research at the University of Adelaide (CASR) was originally commissioned in 2007 to analyse the crash data base for suitable locations for centre wire rope safety barrier in South Australia. CASR produced a list of potential locations, from which Victor Harbor Road emerged as a preferred candidate in 2008. The

method used by CASR to determine the most appropriate roads, was based on head on casualty crashes in SA between 1990 and 2006, where at least one person was treated in hospital or fatally injured. CASR also looked for locations that had at least two other head-on crashes within 2.5km of that location. Road sections identified had repeated head on crashes within a speed zone of 100km/h or 110km/h. (McLean et al, 2008)

Victor Harbor Road at Willunga Hill was further identified for investigation. The project was based on the Safe System approach, recognizing that human error is inevitable. The Safe System principle is about making allowances for human error in the design, construction and management of roads and roadsides to reduce the risk of crashes and minimise the severity of injury if a crash occurs.

As part of the Safe System approach, there is a need to provide a forgiving roadside for those vehicles that will for one reason or another leave the carriageway at speed. There were many hazards present in the roadside throughout the route under consideration; including outdated or deteriorated barriers, unprotected culverts, headwalls, signs, fences and steep drop-offs in the verge.

The objective of the median wire rope safety barrier project is to achieve maximum reduction in crashes and crash severity and to address roadside hazards, head on serious injuries and fatal crashes. It is also a key safety initiative to reduce the consequences of collisions with oncoming vehicles.

A median barrier is a longitudinal restraint system constructed to prevent errant vehicles from crossing or entering opposing lanes of traffic. These cross-over accidents are typically violent collisions with a high probability of serious injury or death. The installation of roadside safety barriers along most of the length of this project was to shield the hazards identified such as large trees, steep drop-offs in the verge, culvert headwalls etc.

This was the first installation of wire rope safety barrier in the centre of an existing four-lane road in South Australia. This section of Victor Harbor Road reduces to one lane each way at the southern end. The general posted speed limit on this section of the road is 100km/h.

This project involved the installation of 2.3 km of wire rope safety barrier along the centre of the Willunga Hill four-lane carriageway section of Victor Harbor Road supplemented with an innovative wire rope tension and impact monitoring system that relays information back to the Traffic Management Centre at Norwood, for timely response. This section of Victor Harbor Road carries an AADT of 10200 vehicles per day and is on an 8.5% grade at this point winding up the Willunga Hill escarpment. A number of serious and fatal crashes had resulted from vehicles crossing the centre line. Over the period 2006-2010, six cross-centerline casualty crashes were recorded (as ‘head-on’, three ‘hit fixed object’ and one ‘roll over’), of which one was fatal and another involved serious injury. The total project cost was approximately \$4 million.

Project Implementation

Road safety works at Willunga Hill included the installation of some 2.3km of central median wire rope safety barrier to protect road users, together with other key road safety treatments such as sealed shoulders and removal of hazardous roadside vegetation.

Pre-existing safety treatments at this location were limited. There was some shoulder sealing and road-side hazard protection, but it was patchy.

- Key safety treatments that have been installed along with the central wire rope barrier include roadside safety barriers (W-beam and wire rope) to protect road users from roadside hazards, such as significant trees, steep drop-offs on the verge and drainage structures.
- The road-side safety barriers used on this project comprised W-beam and Wire Rope at Test Level (TL) 4.
- Sealed shoulders to allow recovery of vehicles that have deviated from the travelling lane.

Two meter wide shoulders were considered appropriate for this project sufficient to allow traffic to pass a stopped vehicle with caution by shifting position in the lane without encroaching into the adjoining lane.

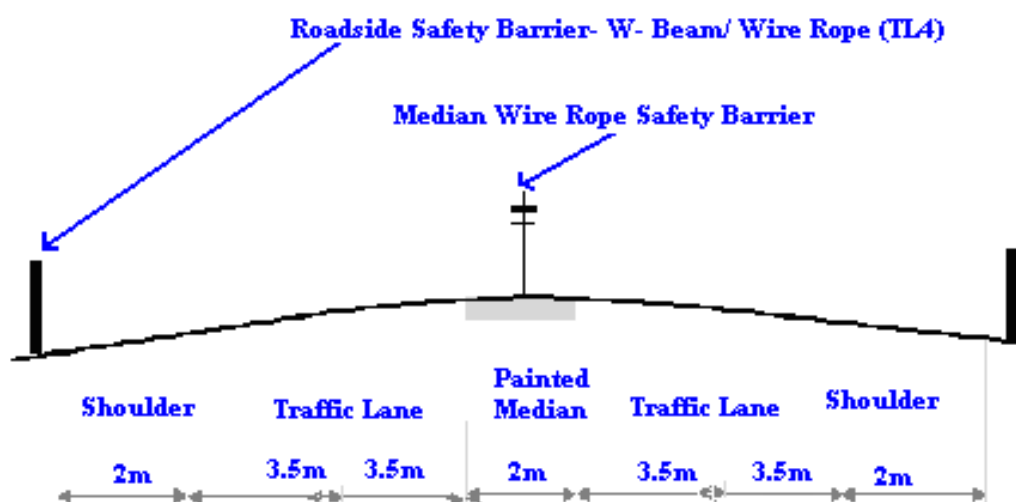


Figure 2

Cross Section dimensions of Median Wire Rope Safety Barrier on Victor Harbor Road at Willunga Hill, South Australia

- Audio-tactile line marking installed on centre lines and edgelines to help reduce vehicle straying and crashes by providing a sound and vibratory warning to drivers as they stray from the lanes.
- Wire rope impact/ tension monitoring system for timely response and to maintain the treatment to ensure it remains effective.



Figure 3
View of median wire rope barrier at Willunga Hill, looking north



Figure 4
Median and roadside wire rope barrier at Willunga Hill, looking north

Literature Review

Swedish Experience

Much of the available information on the effectiveness and economic benefit of median wire rope safety barriers comes from Sweden. (Bergh et al, 2005). Bergh et al report an 80% reduction in the fatality rate from 0.011 (per 100 million vehicle km) on the original 13m wide roads to 0.0017, which is similar to (or less than) the rate on Swedish motorways (0.002). The recommended design concept for a “2+1 design with cable barrier” is given as:

‘Existing roadside areas should be smoothed within the right of way preferably extended to recommended clear zones of 7 to 11m. This means that solid objects, trees etc should be taken away and culvert ends tapered. Side cable barriers should be used at dangerous locations as right bends in rock cuts and on low cuts and all embankments in forest areas.’ (Bergh et al, 2005)

It therefore seems that part of the improved safety performance of the 2+1 roads may come from the treatment of the roadsides, including wire rope barriers as shown in **Figure 5**.

Increased maintenance costs were experienced in the Swedish design due to the limited median width of 1.25-1.50 m for the cross-section of 13-14m. (Bergh et al, 2005)



Figure 5

Example of median and roadside barriers in Sweden (Bergh et al, 2005)

Austrroads Report, 2009

Austrroads published a report in February 2009 on the ‘Evaluation of the Safety Impact of Centre of the Road Wire Rope Barrier on Undivided Rural Roads’. The Project examined five sections along the Pacific Highway in north-eastern New South Wales where wire rope barrier had been installed on previously undivided carriageways with painted centre line.

A before and after analysis of the available crash data for the two years prior and two years after installation of the wire rope barrier treatment was undertaken to examine the effect.

Crash Severity	Crashes	
	Before	After
Casualty	5	1
Tow Away (PDO)	4	10

Table 1

Crashes before/after at wire rope barrier sites, Pacific Highway 2003-2006

The analysis also identified that Property Damage Only (PDO) related crashes increased in the post-installation period as compared to the pre-installation period. In part, this increase can be attributed to a conversion to PDO crashes that may otherwise have resulted in serious injury or even the death of vehicle occupants.

The result of the crash and economic analysis was considered positive and generally supportive of the continued and expanded use of wire rope barrier in the centre of undivided carriageways. (Austrroads, 2009)

However, the report raised issues for ongoing operation include the impact on all road users (including motorcyclists), maintenance requirements, repair delays, method of repair and worker safety.

South Australian Experience on Median Wire Rope Barriers

In South Australia, implementation of such infrastructure was initiated on Port Wakefield Road, National Highway in 2008, commencing at the end of the duplicated carriageways heading north to the Port Wakefield town ship. This location was selected due to previous crash history and from the identified locations considered for the installation of median wire rope safety barrier in South Australia from the CASR report to DPTI titled ‘Median wire rope safety barrier’ in 2008.

Prior to installation, this road section experienced 14 casualty crashes resulting in 4 fatalities, 11 serious injuries and 13 minor injuries for the period 1999-2008.

In the four years since installation in June 2009, 22 hits have been reported with the median wire rope barrier, resulting in just 2 minor injuries and the rest property damage only, potentially saving lives and serious injuries.



Figure 6

Median Wire Rope Barrier on Port Wakefield Road, South Australia

Maintenance and tensioning of wire rope safety barrier is carried out according to DPTI Specifications (Part 843 Maintenance of Wire Rope Safety Barriers) which specifies that wire ropes shall be inspected for corrosion and damage every fortnight, and for tensioning it should not be dated 12 months earlier than the date of verification of tensioning, for which a maintenance contractor is hired for inspection purposes.

In the case of any accident or damage to the wire rope, the maintenance contractor is informed by Traffic Management Centre (TMC), Norwood which relies on this information coming either from the Country Fire Service, South Australia Police or members of the public. This system is not foolproof and needed to be replaced by something reliable, which could communicate directly and improve response times utilizing the TMC for instant notification of crashes and reduce risk for road users.

Research Methodology

The methodology of this study involved the following steps:

- Literature search of maintenance issues for wire rope barrier and the incident management system adopted after a crash with the wire ropes and review of product information.
- Collect Willunga Hill wire rope barrier cross section information, load cell monitoring system design details, crash statistics from DPTI
- Review DPTI guidelines for the maintenance of Wire Rope Safety Barriers.
- Site visits to Traffic Management Centre, Norwood and actual location of load cell installation to understand the monitoring system functions and the reporting system.
- Consultation with key people from DPTI involved in planning, maintenance, field, implementation and installation to identify maintenance issues, limitations and other issues.
- Review Short Message Service (SMS) data and rope tension data received from the monitoring system after a crash.

Load Cell Monitoring System

The objective of this system is to monitor the tension along the median wire rope safety barrier to assist in maintenance, provide notification of impacts and collisions with the barrier and therefore improve the department’s responsiveness to incidents and reduce further consequences on site in the event of a crash.

The barrier was installed in two sections that overlap in the middle, adjacent to the monitoring equipment as shown in **Figure 7**. The sections are approximately 1.0 km each in length. The barrier is continuous across the entry point to the scenic lookout on the northern side of the road and prevents right turn in and out of this access road for safety reasons. There are curves in both sections.



Figure 7

Load cell monitoring system at Victor Harbor Road, Willunga Hill, South Australia.

Two options were initially investigated for the wire rope monitoring system the ‘wireless’ option and the ‘hard wired’ option.

Wireless Option

Two options were explored to store the acquisition enclosure, buried or mounted.

Option 1: Buried

The issue with this option was the limited power supply from batteries which could last only up to 3 months and require regular visits to replace the batteries in the underground enclosure, as shown in **Figure 8**.

Option 2: Mounted on a pole (with a smaller solar panel at the median strip).

This option was better than the first option with respect to power supply, but was considered dangerous due to the high speed traffic and a distraction for the traffic with a pole standing in the middle of the road.

However, the wireless option was dropped primarily because the acquisition enclosure in the middle of road requires power to run. The acquisition enclosure contains wireless sensor node(s) to acquire data and readings from the strain sensors and transfer data wirelessly to the main enclosure (at the roadside). The main enclosure contains a real-time controller and would wirelessly communicate with the acquisition node(s), in addition to perform data storage and 3G/GSM communication/data transfer.

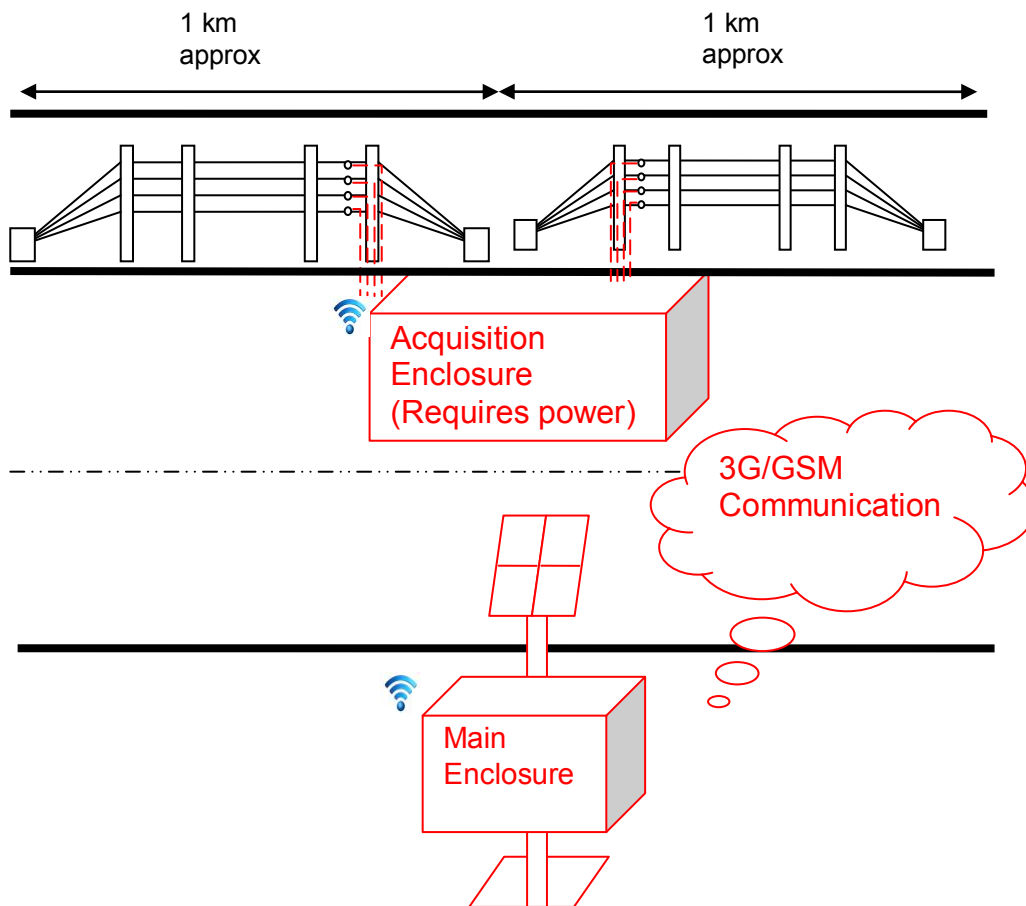


Figure 8

Wireless Option for wire rope monitoring system schematic diagram

Hard Wired Option

Under this option wire tension sensors are attached to the wire ropes as shown in **Figure 7** and connected by a slot cut underneath the road, directly to the main enclosure communications mounted on the roadside as shown in **Figure 10** performs all acquisition, analysis and remote data communications. Slot-cuts are made in the road from the shoulder to the median strip to provide a cable path. **Figure 9** shows the system overview.

The system is set up to monitor two separate barrier sections with a maximum of 8 sensors (4 sensors per section, 1 sensor per rope). Power for the main enclosure is supplied by a solar panel mounted above the enclosure that charges the main battery, as shown in **Figure 10**. The main enclosure is pole mounted with sufficient security measures.

The main enclosure is 3G/GSM communications capable for remote data transfer and for SMS notifications to the TMC at Norwood.

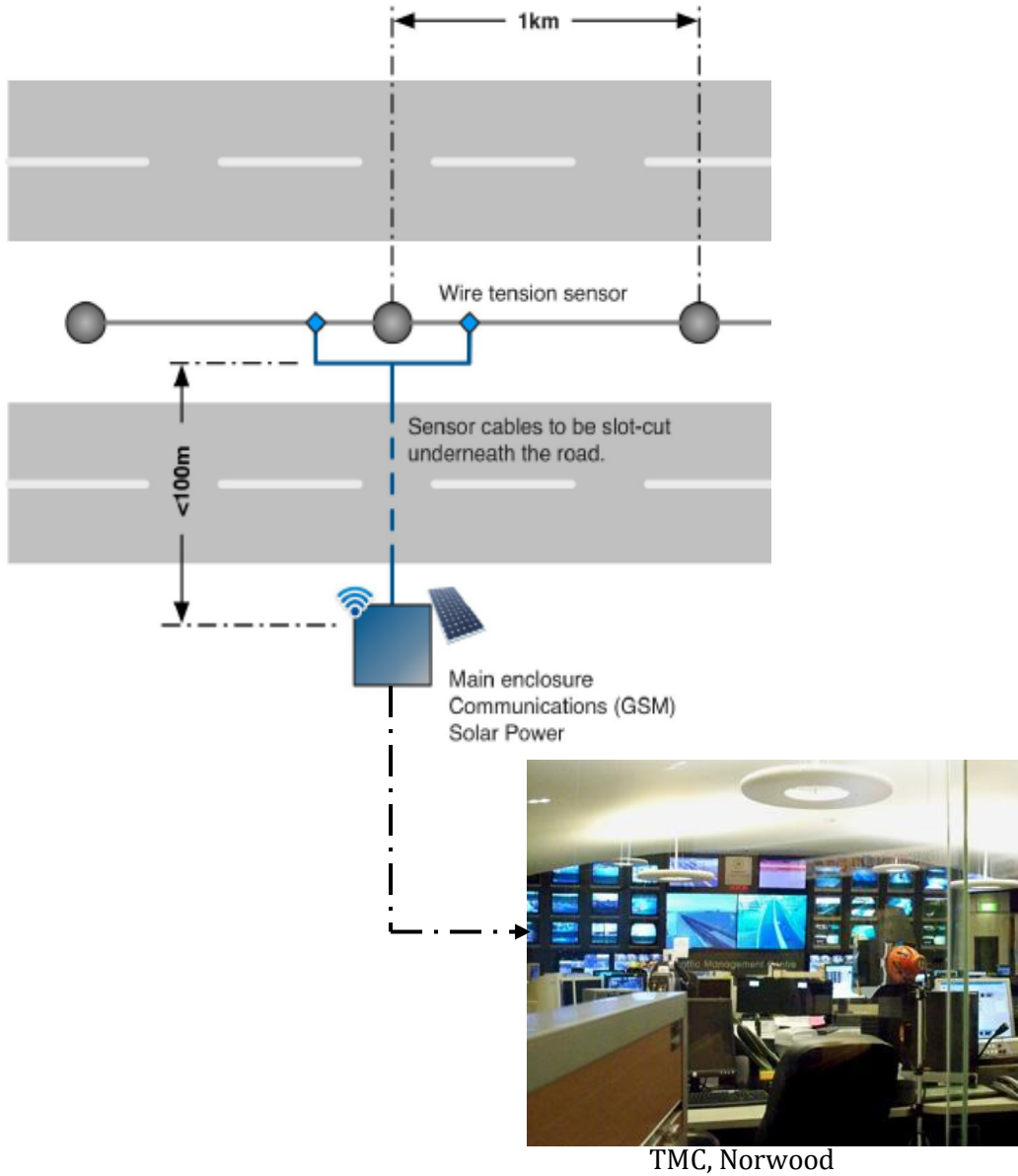


Figure 9
Wire rope monitoring system schematic diagram



Figure 10

Remote monitoring system electronic relay box, main enclosure and solar panel

Remote Monitoring

This component relates to the incorporation of ‘events’ and ‘alarms’ from the load cells into the existing STREAMS¹ system at TMC for responsive action, which is monitored by the TMC operators around the clock.

The STREAMS field processor was configured with a modem to receive tension and other SMS messages from the wire rope system via a new device driver. STREAMS can format the SMS messages it receives for operator viewing and present the messages as Alarms in the Alarm Manager application. The operator can also click on the wire rope installation icon in STREAMS and send an auto SMS to the wire rope system to interrogate the status of the wire rope system such as tensions and battery life.

STREAMS also allows for messages to be created and sent to the wire rope system for manual interrogation. It is also capable of sending a copy of the SMS/ email response to a pre-programmed distribution list for assessment. TMC will then provide accurate and timely information to the maintenance crew, police, emergency services etc depending on the severity of the accident.

All alarms are recorded in STREAMS and in the TMC call management system. When the operator receives the alarm; the following protocol has been determined:

Major alarm – The operator will notify SAPOL (South Australia Police) and despatch Maintenance crew. An e-mail will be sent to all stakeholders that the wire rope has lost tension.

Medium alarm - The operator will advise the Maintenance crew. An e-mail will be sent to all stakeholders that the wire rope has lost tension.

¹ *STREAMS is a MS Windows compatible ITS platform developed by Transmax that supports a comprehensive range of services and infrastructure making it possible to run numerous traffic services in a single system.*

Minor alarm – The operator will e-mail will be sent to all stakeholders that the wire rope has lost tension.

The Maintenance crew (Asset Maintenance Unit) is able to send a text message such as ‘check tension mean’ or ‘check temp mean’ from any mobile phone to the wire rope system for remote interrogation of the current tension and temperature readings. This system is also capable of remotely turning off one or more faulty sensors or cabling.

A simple laptop based Graphical User Interface with real time data display has also been designed by the service provider ‘Vipac’ for DPTI users to connect to the system and download data in excel format on site.

Benefits of Load Cell Monitoring System

- This system will trigger an alarm at TMC for immediate response when the wire rope is hit or out of tension rather than waiting for the police or the public to report an incident or routine inspection.
- The maintenance crew is able to organize repair and maintenance works more efficiently and with better response times.
- Cost savings on the normal maintenance cycle of wire rope (i.e. eliminate the need to inspect the wire rope on a regular basis since tension levels can be checked via SMS).
- The median wire rope is monitored at all times for improved road safety.
- Reduced risk for DPTI

Discussion

Current centreline widths on most two lane rural roads leave virtually no room for driver error and only small lapses in concentration due to fatigue or distraction can lead to disastrous consequences. South Australian experience and research findings suggest that the use of median wire rope barriers will reduce impact severity to the point that only a small proportion of crashes are recorded casualty crashes.

Some key issues with median wire rope barrier had been noted such as: community perception of greater risk for motorcyclists; and more maintenance and nuisance damage than other types of barriers.

One of the reasons motorcycle protection barrier (post protectors) was not used as part of this project was due to the low number of motorcyclists travelling along this section of Victor Harbor Road. A review of the crash history for the 5 year period from 2006 to 2010 identified no crash involving a motorcyclist. In addition to this, there were maintenance issues raised in the case of being a hit by a car, the motorcycle barriers usually need to be replaced as they tend to shatter and leave debris on the side of the road, so new ones need to be available at all times.

Calibration of the load cell monitoring system has been required to increase accuracy of the output. The System was set to send out messages when there is a significant change in tension over a short duration of time. This was done to eliminate variables like temperature effects.

For the future CCTV (Closed Circuit Video Cameras) may be installed at the site to monitor incidents along with VSLs (Variable Speed Limit Signs) to assist in controlling traffic safely in a event of crash.

To date the median wire rope at Willunga Hill has experienced two hits resulting in property damage only, with barrier damage from one strike as shown in **Figure 11**.



Figure 11

Damaged wire rope posts at Willunga Hill after being hit

Also, anecdotal evidence from a length of median wire rope recently installed further north of these sections indicates that the installation of audio-tactile line marking either side of the wire rope has had a significant effect in reducing impacts into that barrier. This would assist to reduce nuisance hits into the wire rope and thereby reduce maintenance costs.

Conclusion

This is the first application of median wire rope barriers on an existing four-lane road and in hilly terrain in South Australia. Recent and approved practices in SA as well as overseas and interstate were reviewed with internal consultation to concur on the preferred cross section with respect to the road function and the expected benefits and costs.

The electronic remote monitoring system (using load cells) is understood to be the first such application in Australia for immediate notification and response. The median wire rope system completed early this year forms just a part of the response by DPTI to address the incidence of head-on collisions and cross-centreline type crashes.

The relatively short period of operation (from July 2013) of the subject, monitoring system has resulted in a limited amount of data being available for analysis. Other States have indicated interest in the remote monitoring system employed on this project.

DPTI is continuing to monitor the tension along the median wire rope safety barrier, to assist in maintenance and to provide notification of impacts and collisions with the barrier and therefore improve the department’s responsiveness to incidents. This is a positive road safety outcome and is supportive of the Safe System approach adopted by the DPTI, since every incident represents a potential head-on (or other) crash being averted by the action of the median wire rope installation.

Recommendations

The study has identified issues as mentioned above and recommends the following:

- Subject to satisfactory performance, dedicated resources should be identified within a project or retro-fitting of monitoring system to other high risk crash locations to align with the Safe System approach.
- There may be a case to review criteria for motorcycle protection systems with median wire ropes.

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