EFFECTIVENESS OF USING CAT-EYE REFLECTORS AS WARNING AND TRAFFIC CALMING DEVICES IN LOCAL ROADS AND HIGHWAYS

Hamdy Faheem, PhD
Associate Professor, Civil Engineering Department, Faculty of Engineering, Minia University, Minia 61111, Egypt, e-mail: drhamdyfaheem@gmail.com

Submitted to the 3rd International Conference on Road Safety and Simulation, September 14-16, 2011, Indianapolis, USA

ABSTRACT

Cat-eye reflectors are retroreflective safety devices that can be used effectively in road marking to provide directional guidance on roadways. This paper examines the effectiveness of using transverse cat-eye reflectors in the driving lane as warning and traffic calming devices. Field measurements of speed and in-depth interviews with different driver groups were used to assess the potential benefits of using cat-eye reflectors in these applications. The results show that cat-eye reflectors, when used as traffic calming devices in urban area, can effectively reduce the speed in local streets. However, they have a minor effect in reducing speed on highways. Cat-eye reflectors can also be used as warning devices on both highways and local roads to alert drivers about the need to take action. The results of in-depth interviews with drivers showed that drivers prefer cat-eye reflectors over other alternatives such as rumble strips. Heavy vehicle drivers seem to be the driver group that favors the use of cat-eye reflectors the most among other driver groups.

Keywords: Road Safety, Transverse cat-eyes, Traffic calming device, warning device

1. INTRODUCTION AND BACKGROUND

Traffic calming has been defined as ‘‘the combination of mainly physical measures that reduce the negative effects of motor-vehicle use, alter driver behavior, and improve conditions for non-motorized street users’’ Lockwood (1997). Traffic calming measures are intended to be self-enforcing. Second, as defined by the ITE subcommittee, traffic calming measures rely on the laws of physics rather than human psychology to slow down traffic.

Traffic calming had its genesis in The Netherlands Schlabbach (1997), in the form of ‘‘woonerfs,’’ or residential precincts, designed to limit the mobility of motor vehicles in neighborhoods. A road hump with an elevation of 8 cm (3.1 in), installed at the end of an alley in Delft in 1970, was the first traffic calming fixture. By 1976, regulations that incorporated traffic calming features into design standards had been established. The success of the speed inhibiting measures used in the Netherlands led other European countries to experiment with these devices. Germany began experimenting with narrowings, roundabouts, and textured surfaces around 1977 (Schlabbach, 1997; Ewing, 2000). These devices proved to be as successful in Germany as they were in the Netherlands Ewing (2000). Similar traffic calming programs were developed in Norway, Sweden, Switzerland, England, France, Austria, Israel, and Japan Ewing (1999). Pharaoh and Russell (1991) observed that speed humps were rejected in Germany, but were employed extensively in Denmark and The Netherlands. In Denmark, speed humps were considered to be necessary for effective speed reduction. In The Netherlands, speed humps were being used to demarcate the boundaries of 30 km/h (19 mph) calmed streets; 50 km/h (31 mph) humps were being used on roads that provide access to residential streets De Wit and Talens (1998). Brindle (1997) reported that traffic calming concepts were borne in Great Britain during the 1960s; piecemeal and ‘‘patchy’’ applications followed there and in Australia during the 1960s and 1970s. Formal policies and standards were eventually developed, partially in response to the progress in continental Europe. There have been ‘‘a great deal of surveys and research works’’ on traffic calming in Europe Schlabbach (1997), but only a few of them isolate the effects of specific features such as speed humps. That is, most European studies have concentrated on the impacts of integrated traffic calming strategies. Atkins (1999) suggested that traffic calming techniques had been used in a few U.S. cities since the late 1940s. Several U.S. cities developed traffic calming programs during the 1980s to address citizen concerns; by 1996, over 100 cities and counties reported the use of at least one calming measure.

The main aim of traffic calming devices is to decrease speeds used by drivers to the degree that they do not exceed acceptable speed levels. The slowing down effect of the calming devices is based on their detrimental effect on the driving comfort when the speed of the vehicle exceeds the desired level. Single calming devices or devices placed too far apart are only effective at one point. The best traffic calming solution is the one that reduces speeds over the entire stretch of the road. Excessive speed is a major problem within roadwork sites. When drivers do not adequately adapt their speed to these conditions, they increase their risk of accident involvement Fildes and Lee (1993). Indeed, excessive speed is currently a primary contributory factor in roadwork-related accidents around the world (Australia Department of Infrastructure, Transport, Regional Development and Local Government, 2009; New Zealand Ministry of Transport, 2009; United Kingdom Department for Transport, 2009). In addition to the impact on human lives, speeding, particularly during non-work hours, often damages roadwork machinery, signage and the road surface, necessitating otherwise unnecessary road repairs and prolonged job completion times (Duynhoven, 2005; Miller, 2005). Traffic calming devices has been found to be particularly effective at reducing vehicle speeds, and thus the frequency and severity of accidents. Several studies have demonstrated a clear relationship between speed and accidents (Salusjärvi, 1981; Finch, Kompfner, Lockwood and Maycock, 1994). The Oregon DOT reported speed statistics indicating that there is an 85% likelihood of death for a pedestrian struck at 40 mph. One struck at 30 mph has a 45% chance of being killed, and the risk drops to 15% if the pedestrian is struck at 20 mph (ODOT 1999).

Since the early studies that were carried out by the Transportation Research Laboratory (UK) in the 1970s to examine their effectiveness Watts (1973), the use of vertical raisings of the road pavement as a passive method for controlling the speed of vehicles has become common in many countries. To date, several types of these devices have been introduced following the same basic principles, but with different levels of effectiveness and level of comfort. They can be classified as: speed bumps, speed humps, and speed cushions. The first two are characterized by a continuous vertical deflection placed across the street but with a range of different dimensions. From the viewpoint of the effect on vehicles, speed bumps produce impacts that are often dangerous for the suspension system and are a source of high levels of discomfort, especially for some categories of road users, such as cyclists, motorcyclists and occupants of emergency vehicles. Moreover, many drivers have found that an increase in speed, within a certain range, tends to reduce the magnitude of the vertical acceleration, consequently forcing the vehicle to increase its speed to attenuate the jolt and thus producing a significant reduction of the effectiveness of such a device (Watts, 1973; Kassem and Al-Nassar, 1982). On the other hand, the lower ramp of the speed humps and their special profiles allow the vehicle to gently straddle the undulation, at the same time forcing the driver to reduce the speed to suitable values in order to avoid a catastrophic jump over the road pavement.

The analysis of drivers' response to installation of such raisings shows that users prefer larger humps since they are more comfortable in terms of jolts perceived inside the car, (Watts, 1973; Hodge, 1993; Webster and Layfield, 1998) a fact that is also confirmed by the values of internal vertical acceleration.

Previous tests focusing on the assessment of undulation effectiveness in terms of speed reduction always showed a decrease in the 85th and 50th percentile of speed (Sumner and Baguley, 1979; Mak, 1986; Vis et al., 1992; Layfield and Parry, 1998; Webster, 1998; Webster and Layfield 1998). The influence of traffic calming measures on driver's behaviour can be considered exhausted at a distance more than 100 m before or after the device (Mak, 1986; City of Portland and Bureau of Traffic Management, 1998) and that distance will be decreased to about 50 m in case of low speeds (local streets).

In rural highway sections, the drivers maintain high operating speeds and generally they do not adequately reduce speeds when passing through small urban areas (DfT, 2000, 2005; Hallmark et al., 2007; NRA, 2005). Frequently, the transition from the rural to urban environments relies only on the posted speed limit Van Schagen (2003), and this condition is totally inadequate to induce appropriate behaviors.

It was found that, on average, all types of speed management schemes reduced accidents. Schemes with vertical deflections (such as speed humps, tables or cushions) offered the largest and most consistent percentage accident reductions (County Surveyors Society (1994))

Traffic calming devices, such as speed humps, speed bumps, speed tables, roundabout, transverse rumble strips, optical speed bars, textured pavement, and cat-eye reflectors are spreading across Egypt; with the first and last devices being the most common.

2. PURPOSES OF THE STUDY

Major highways pass through small urban/rural communities with high speeds limits outside their limits and a reduced speed section throughout the urban/rural areas. Consequently, drivers passing through these communities often maintain such high speeds throughout these areas. When speeds in urban/rural communities are problematic, traffic calming devices provide a potential solution. In Egypt, transverse cat-eye reflectors are commonly used in local roads and highways as traffic calming and/or warning device. The aim of this research is to evaluate the effectiveness of cat-eye reflectors in local roads and highways. Field measurements of speed and in-depth interviews with different driver groups were performed.

3. CAT-EYE REFLECTORS

Cat-eye reflectors are retroreflective devices that can be effectively used in pavement marking to provide directional guidance on roadways. The idea to use cat-eye reflectors was originated in the UK in 1933 and today they are used throughout the world. If placed across the entire width

of the roadway surface, they cause sound and vibration to alert drivers to changing conditions. Cat-eye reflectors are currently also used in Egypt as a traffic calming device in both local roads and major highways. Due to the differences in the characteristics of traffic operations, their effect in reducing speed and alerting drivers may differ in local roads than in major highways.
Different shapes and sizes of cat-eye reflectors are currently used in Egypt: small size with dimensions of 12cm *12cm and height of 2.0 cm and large size with dimensions of 19.5cm *19.5 cm with height of 3 cm. There are many geometric arrangements of cat-eye reflectors on the roadways. They can be arranged perpendicular or diagonal to the roadway edges. Figure 1 shows one configuration of cat-eye reflectors in which the reflectors are installed in parallel rows (5 to 12 rows) and span the width of the road.

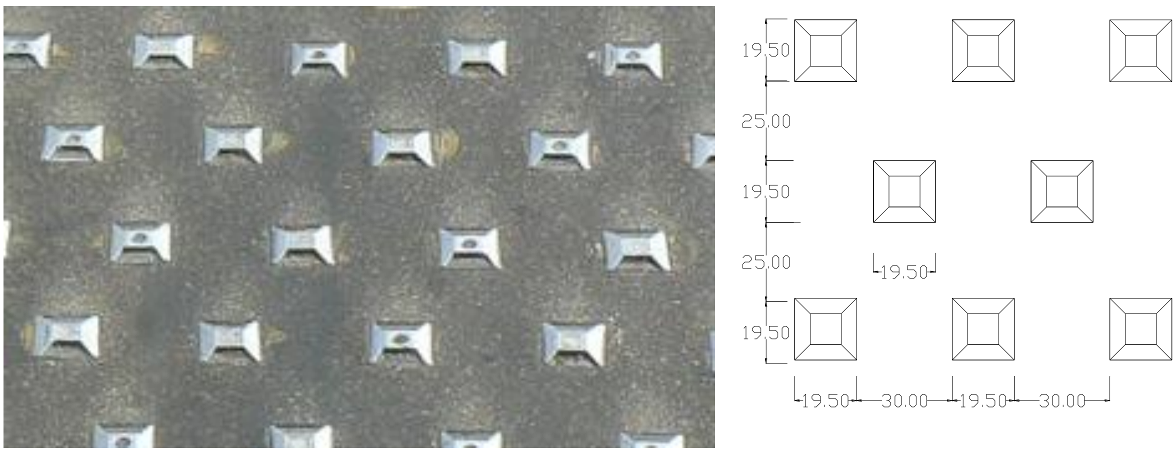

Figure 1 One configuration of cat-eye reflectors.

3.1 Advantages of Cat-eye Reflectors

a. Self-warning
b. Easy to install compared to other devices
c. No damage to the vehicle or loss of control will occur if the driver do not notice them and pass over them with high speed.

3.2 Disadvantages of Cat-eye Reflectors

a. Some drivers increase vehicle speed to overcome their effect. This may cause negative safety effect.
b. Cat-eye reflectors require a high level of maintenance. With time, some cat-eye reflectors, especially near the edges of the roadway may get detached or embedded in road surface, causing potential reductions in the effectiveness of the device.

4. SPEED MEASUREMENTS

To evaluate the effectiveness of cat-eye reflectors, data were collected using Digital video cameras. For local roads, data were collected both upstream and downstream the cat-eye device location. For highways, data were collected upstream of the device only. Field observations showed that, in major highways, the change of speed was limited in the vicinity of the device location. To determine vehicle speed from recorded videos, transverse white lines were painted across the span of the lanes on the roadway surface every 5 or 10 meters for 100 meters upstream and downstream from the device. Vehicle speeds were calculated by dividing the distance between any 2 lines (10-meter) over the elapsed time, which can be determined from the videos with a high degree of accuracy. To increase the accuracy of the speed measurements, the distance between the transverse lines that mark the distance was reduced to 5 meters just around the device, by adding 2 white lines 5-meter upstream and downstream of the device (base line 5-meter just around the device). At each study location, a minimum sample size of 300 vehicles was used. This sample size was assumed to be adequate to determine the speed profiles at the study locations. In urban area, from field observation, it was noticed that most of drivers are familiar with the streets conditions and the locations of speed calming devices. As a result, and in addition to the low operating speed, most of drivers start to reduce the speed gradually approximately 60 meters or less upstream from cat-eye reflectors location. The most effective distance in speed reduction was the last 20-30 meters just upstream from the device.

5. STUDY LOCATIONS

Two different groups of study locations were selected in this study. The first group of test sites was located on a major highway that runs north/south (Cairo-Aswan agricultural highway). This highway is a four-lane divided highway at the study location with a posted speed limit of 90 km/h reduced to 60 km/h in urban areas throughout the city. Two locations were selected on straight sections to minimize the influence of geometric features of the highway. The sites were also selected a least 2km away from any traffic signal and at least 250 m away from any intersection. The first location is on the southbound approach (from Cairo to Aswan) and the second location is on the northbound approach (from Aswan to Cairo). The second group of sites involved local roads inside the City of Minia. Three locations were selected, two of them are in Taha Hussein Street and the third was in Kornish Al Nile Street for the north to south direction. Figure 2 shows sample to cat-eye reflectors at one site and Figure 3 shows Study locations on Cairo-Aswan agricultural highway and inside Minia city.

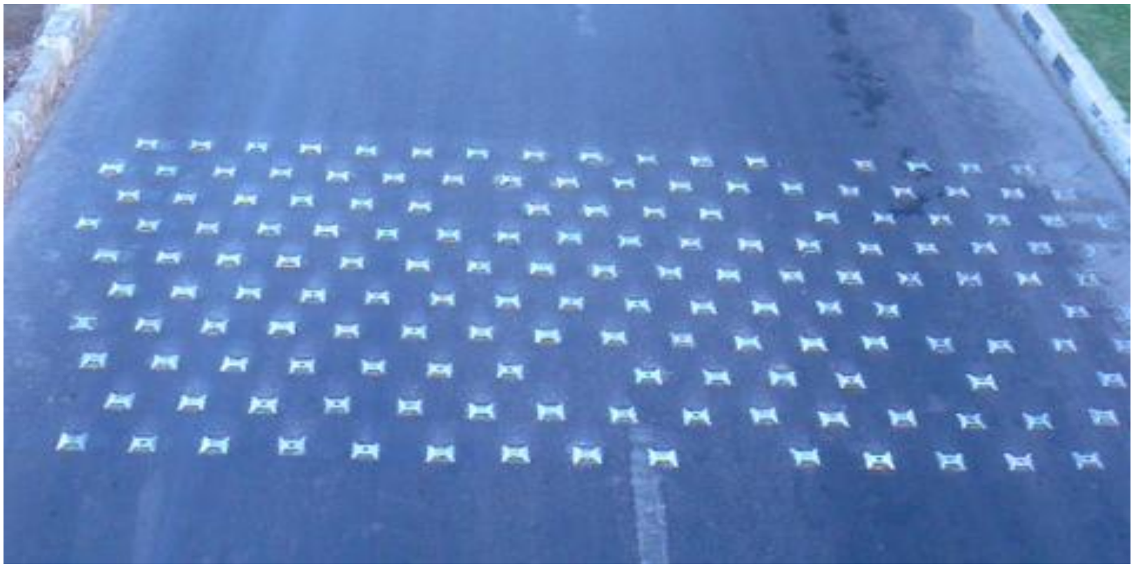

Figure 2 Sample to cat-eye reflectors at one site

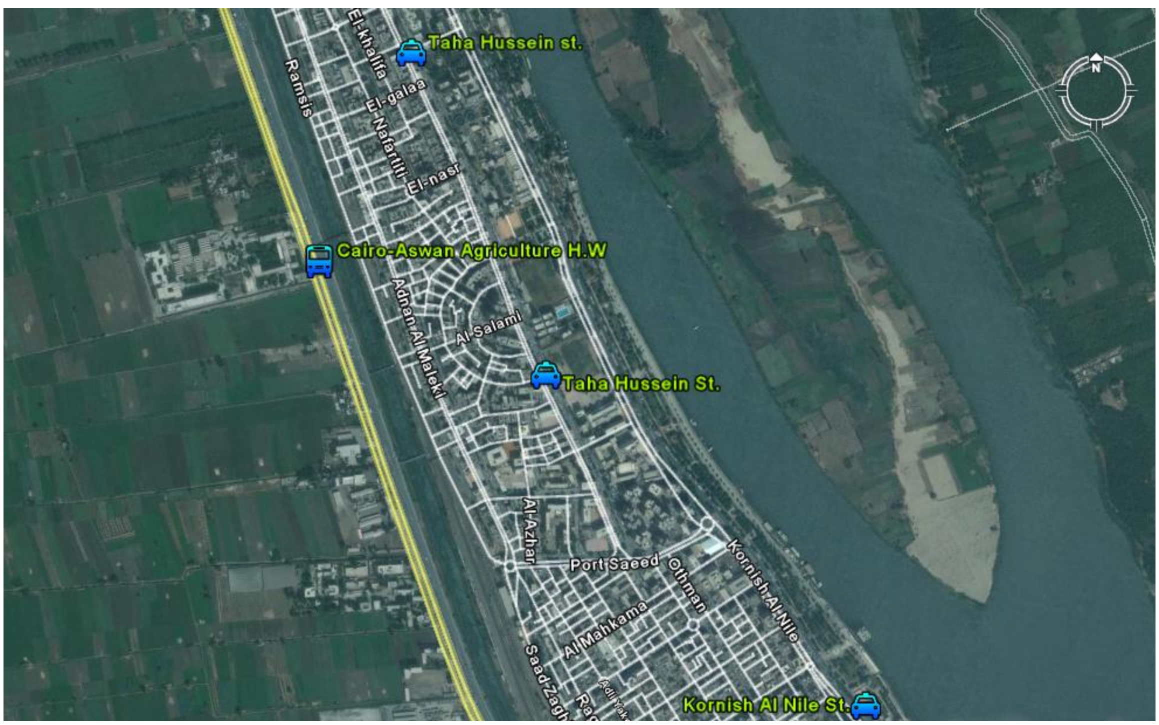

Figure 3 Study locations on the highway and inside Minia city

6. MEASURES OF EFFECTIVENESS

Several different measures are frequently used to evaluate the effectiveness of traffic-calming treatments. As the main objective of these devices is to improve safety, a reduction in crashes is the best measure of effectiveness for a traffic-calming measure. However, a before-and-after analysis to evaluate the safety effect typically requires 3–5 years of before and after crash data. There was not enough information available to conduct a crash analysis. Reduction in speed is the typical surrogate measure used to evaluate the safety effectiveness of traffic-calming strategies. The speeds measured are typically spot speeds. Average speed and the 85^{th} percentile speed are the two metrics used in this study to evaluate the effectiveness of traffic-calming measures.

7. IN-DEPTH INTERVIEWS RESULTS

In addition to the field measurements, in-depth interviews with different drivers were performed. A total of 200 drivers were surveyed during 2010. The results of the survey can be summarized as follows:

1- Approximately, 96 percent of the drivers stated that they do not reduce their speed when passing cat-eye reflectors on highways.
2- Approximately, 10 percent of drivers doubt that cat eye reflectors can harm vehicle tires.
3- All drivers believe that cat-eye reflectors are important at night as directional guidance.
4- Approximately, 40 percent of drivers, especially heavy vehicles drivers, believe that cat-eye reflectors are important as warning device especially at night.
5- All drivers prefer cat-eye reflectors as warning device on highways and asked to put it at specific locations, such as before horizontal curves and before speed humps because pavement markings of such devices fade over after short time. Drivers also asked to put it on highways at distance 30 to 50 km to alert sleepy drivers.
6- About 7 percent of motorist approaching cat-eye reflectors slow down slightly, as a result of taking their feet off the accelerators on highways.
7- All drivers can avoid cat-eye reflectors detrimental effect on the driving comfort by passing the device with low speed ‘speed less than 20-25 km/hr or passing it with high speed ‘the speed over 55-60 km/hr.
8- 94 percent of the drivers reduce speed when passing cat-eye reflectors on local roads because of their low speed.
9- 60 percent of the drivers prefer low speed hump over any other types of traffic calming measures.
10- 40 percent of drivers prefer cat-eye reflectors because if they pass it with high speed accidentally they will not damage a vehicle or lead to a loss of control.
11- 40 percent of drivers especially taxi drivers do not prefer cat-eye reflectors as the shaking caused by the device requires a lot of maintenance to their vehicles.
12- All drivers agreed that no signing and marking is essential to warn drivers of cat-eye reflectors presence, they can notice it from far distance and take the required action (it is self warning).

8. RESULTS AND DISCUSSION

From field observations, cat-eye reflectors have been shown to be effective at reducing speeds in the vicinity of the device. This research was done to evaluate how drivers react to the devices in terms of how vehicles speeds changes with respect to the location of the device. Mean speeds were compared at all locations along a distance of 180 meters around the device (90 meters upstream from the device and 90 meters downstream from the device). Speed data was analyzed upstream of the device, at the location of the device, and downstream from the device.
The 85th percentile speeds were calculated for each roadway section. The average 85th percentile speed upstream from the cat-eye location was 80.43 km/h. The average 85^{th} percentile speed at the cat-eye location was 77.79 km/h, approximately 3.3 percent down from the speed 90

m upstream from the cat-eye location. The results show that the reduction in mean spot speed was minor on highways. Average spot speed was reduced from 67.41 km/h upstream from the cat-eye location to 63.56 km/h at the cat eye location, a reduction of approximately 5.7 percent, which can be considered quite low for this class of speeds. Also cat-eye reflectors reduced the number of vehicles exceeding the speed limit in the immediate vicinity of the device in local roads (more than 96 percent of the sample reduces the speed to less than 25 km/h).

In case of highways, some motorist approaching cat-eye reflectors slow down slightly, probably as a result of taking their feet off the accelerators. The deceleration appears to be fairly uniform until the device is reached. The reason of this action is known from the interview results with drivers. About 10 percent of drivers doubt that cat-eye reflectors may harm vehicle tires; no specific tire damage as a result of cat eye reflectors was recorded from any of the interview sample drivers. Interviewees reported that the device influence can be minimized by either passing through the device with speeds less than 20-25 km/hr or passing through the device with speeds over 55-60 km/h'. In speed range of 20/25 km/h to 55/60 km/hr, the device cause shaking with certain level that depends on the suspension system of the vehicles, cat-eye reflectors configurations, and cat-eye reflectors sizes. Results show that the effect of the cat-eye reflectors can be considered quite local, which means that speed reduction is concentrated in a short distance of about 30–60 m upstream and downstream from the device. Although cat-eye reflectors seem to affect drivers' behaviour to some extent, their effectiveness as speed reducing devices is quite far from optimal. Previous studies (Mak, 1986; City of Portland and Bureau of Traffic Management, 1998; Barbosa et al., 2000) have shown that speed should decrease and reach its minimum value at the device location, then increase to original values. The spatial range in which the speed decreases represents the influence zone of the undulation; the longer this region is the more effective the device is. The results from the local road sites showed that once the vehicles had crossed the device, drivers tended to increase their speed quickly to reach their initial speed levels within a short distance. This observation confirms the existence of an influence region ranging from 30 to 60 m. The detailed results from the two highway test sites and the three local test sites are presented in the following sections

8.1 Highway Test Sites

Figure 4 shows the speed profile data for a sample of vehicles at the Cairo-Aswan agricultural highway northbound direction test site. Figure 5 shows the results for the Cairo-Aswan agricultural highway southbound direction test site. In addition, the change in the 85th percentile speed and mean speed, and distances as a function of the distance from the device is shown in Figures 6 and Figure 7, respectively.

A comparison between the speed at cat-eye reflectors and the free flow speed, speed 90 meters upstream from the device, at the 2 locations of highway shows that the reduction in mean spot speed was minor on highways. The Average spot speed was reduced from 67.41 km/h to 63.56 km/h, approximately 5.7 percent. The average 85th percentile speed was reduced from 80.43 km/h to 77.79 km/h, approximately 3.3 percent. The reduction was larger in the southbound direction than in the northbound direction. This may be due to the fact that cat-eye reflectors in the northbound direction were relatively newly installed. The decrease in speed induced by the presence of cat-eye reflectors can be considered quite low for this class of speed. Statistical analyses shows no significance difference between the mean speed upstream the device and the mean speed at the device location (*p-value* = 0.16). There is no statistical evidence supporting the hypothesis that cat-eye reflectors are effective in reducing devices on highways.

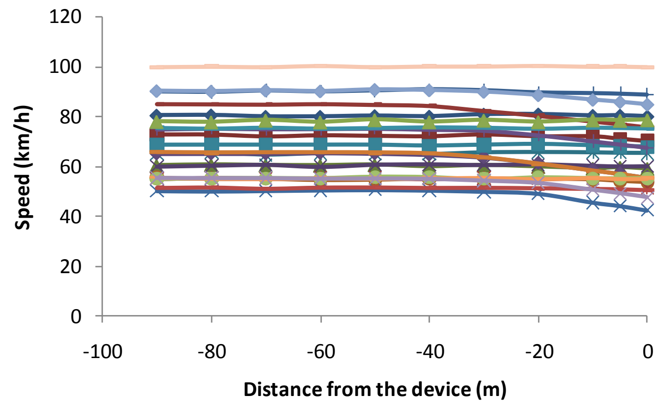

Figure 4 Speed profile sample for Cairo-Aswan agricultural highway northbound direction

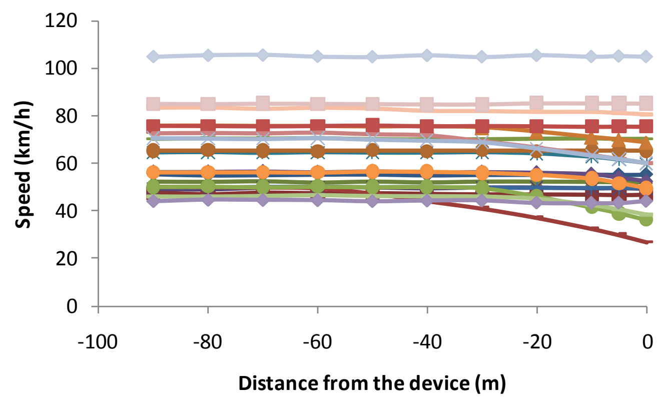

Figure 5 Speed profile sample for Cairo-Aswan agricultural highway southbound direction

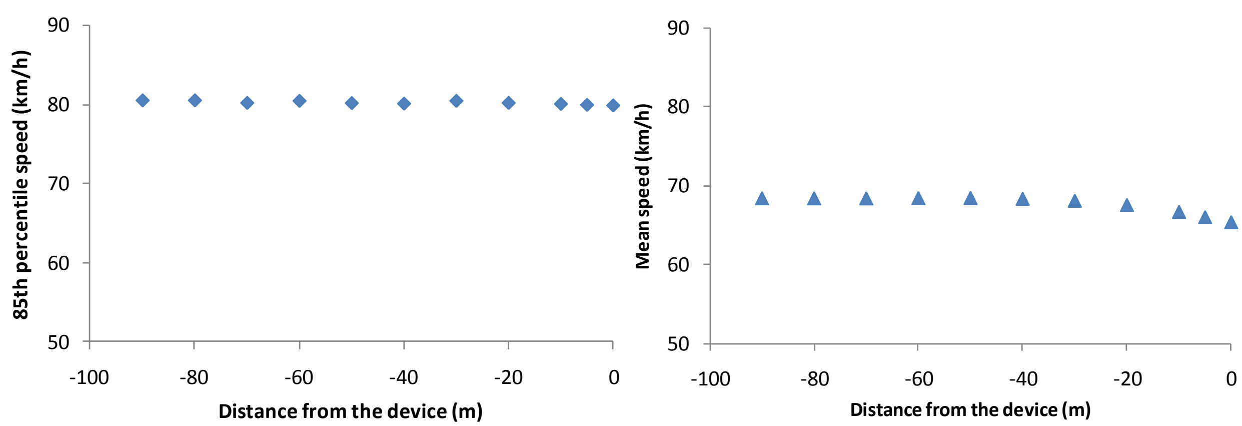

Figure 6 Mean and 85th Percentile speed for Cairo-Aswan agricultural highway northbound direction

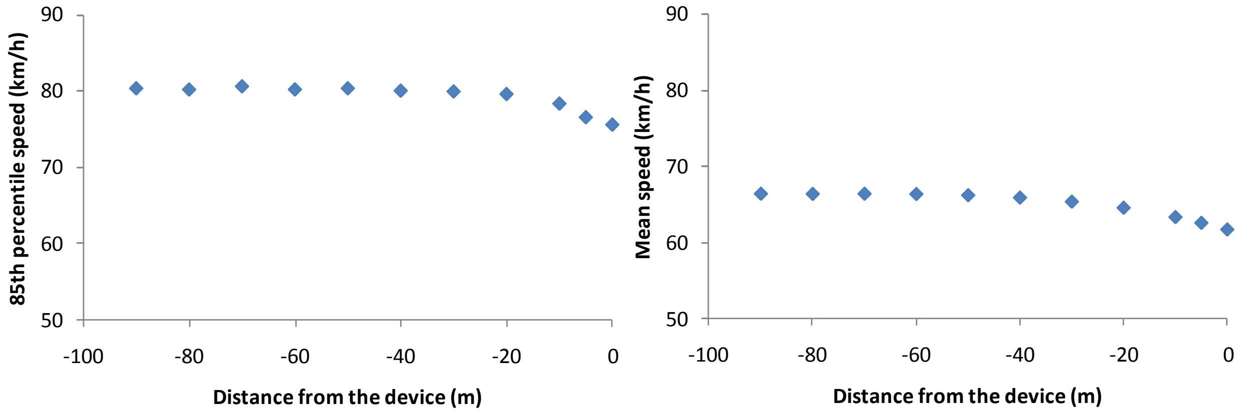

Figure 7 Mean and 85th Percentile speed for Cairo-Aswan agricultural highway southbound direction

8.2 Local Roads test Sites

Figure 8 shows speed profile for a sample of vehicles for the Kornish Al Nile Street southbound direction. Figure 9 shows speed profile for a sample of vehicles for the Taha Hussein street southbound direction, and Figure 10 shows speed profile for a sample of vehicles for Taha Hussein street northbound direction. The change of the 85th percentile speed and mean speed as a function of the distance from the device are represented for the three sites in Figures 11, Figure 12, and Figure 13, respectively.

Comparing the speed at cat-eye reflectors and the free flow speed, speed 90 meters upstream from the device, at the 3 local roads test sites show that the reduction in mean spot speed was significant at the three sites. Average spot speed was reduced from 44.13 km/h to 15. 6 km/h, approximately 64.6 percent and average 85th percentile speeds was reduced from 44.65 km/h to 16.2 km/h, approximately 63.4 percent. The results show that cat-eye reflectors are effective in local road within city limits. The low operating speeds at this roads forces drivers to reduce their speed to about 15-25 km/hr. The decrease in speed induced by the presence of cat-eye reflectors can be considered high effect. Statistical analyses show that the differences in average speeds upstream from the device and at the device location are highly significant (*p-value*=0.0001). There is enough statistical evidence that support the hypothesis that cat-eye reflectors are effective as speed reducing devices on local roads.

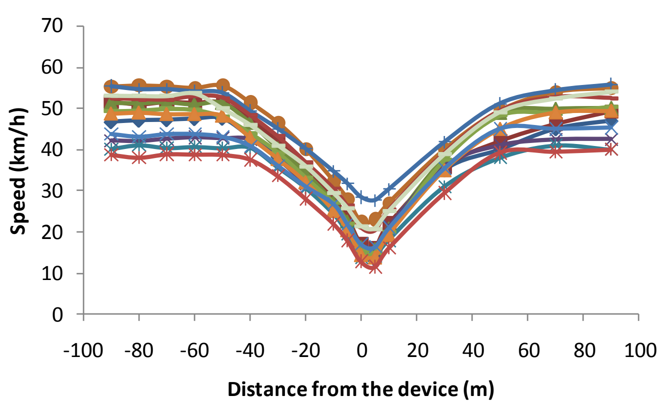

Figure 8 Speed profile sample for Kornish Al Nile Street southbound direction

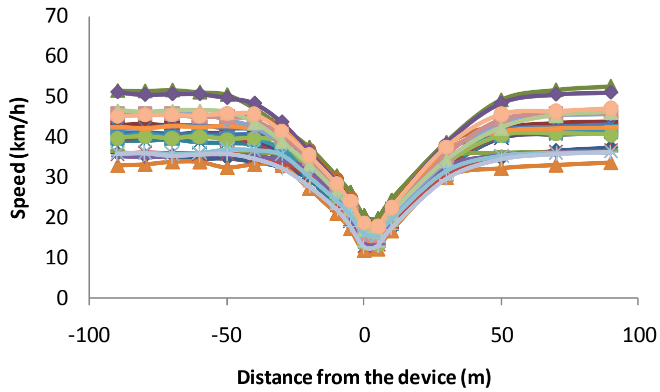

Figure 9 Speed profile sample for Taha Hussein street southbound direction

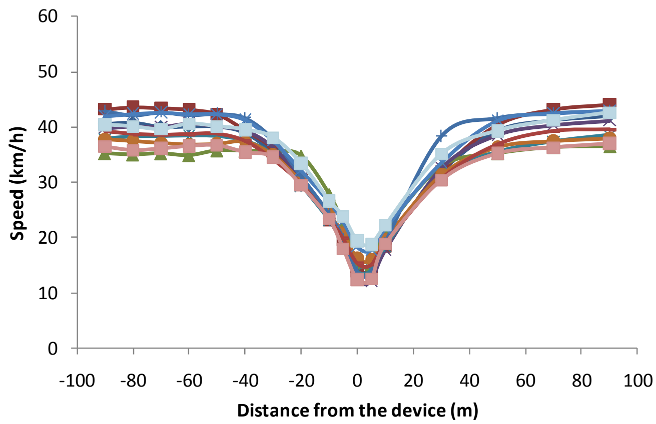

Figure 10 Speed profile sample for Taha Hussein street northbound direction

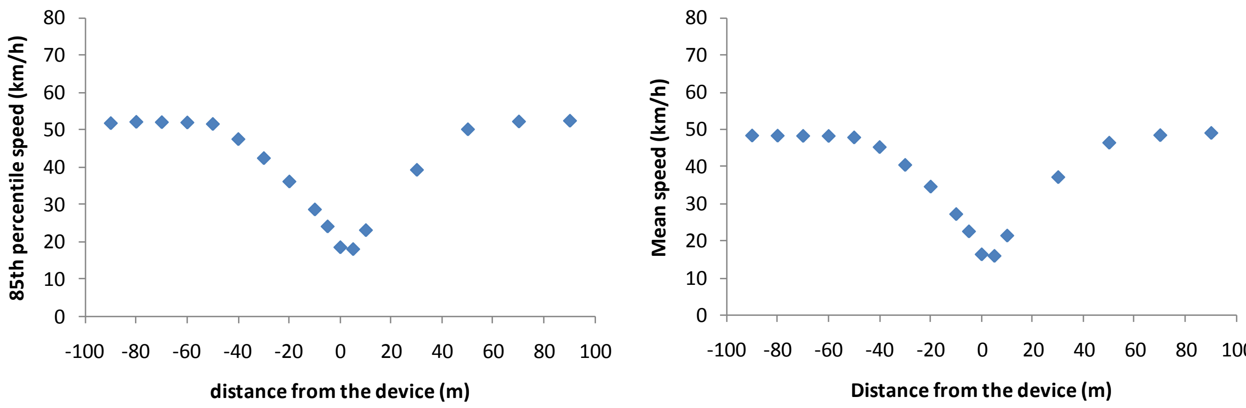

Figure 11 Mean and 85th Percentile speed for Kornish Al Nile Street southbound direction

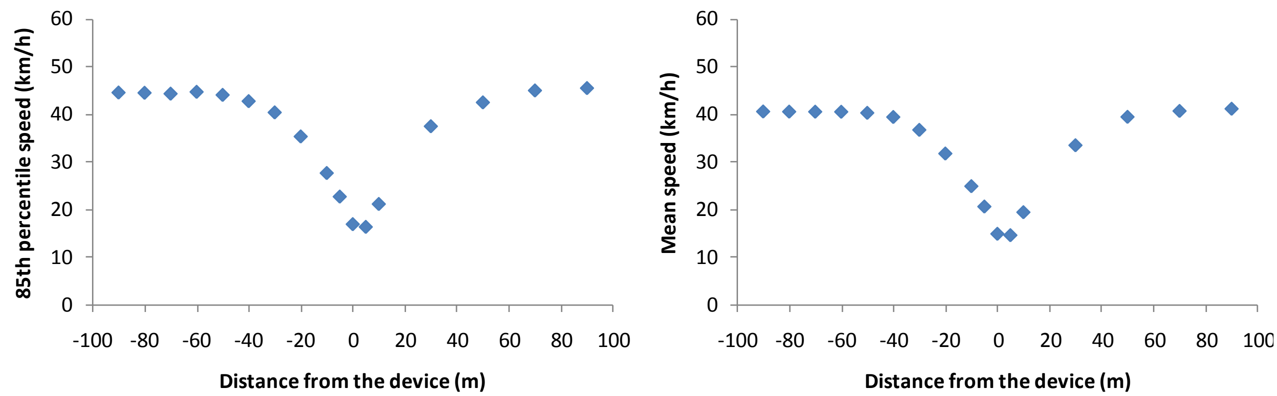

Figure 12 Mean and 85th Percentile speed for Taha Hussein Street southbound direction

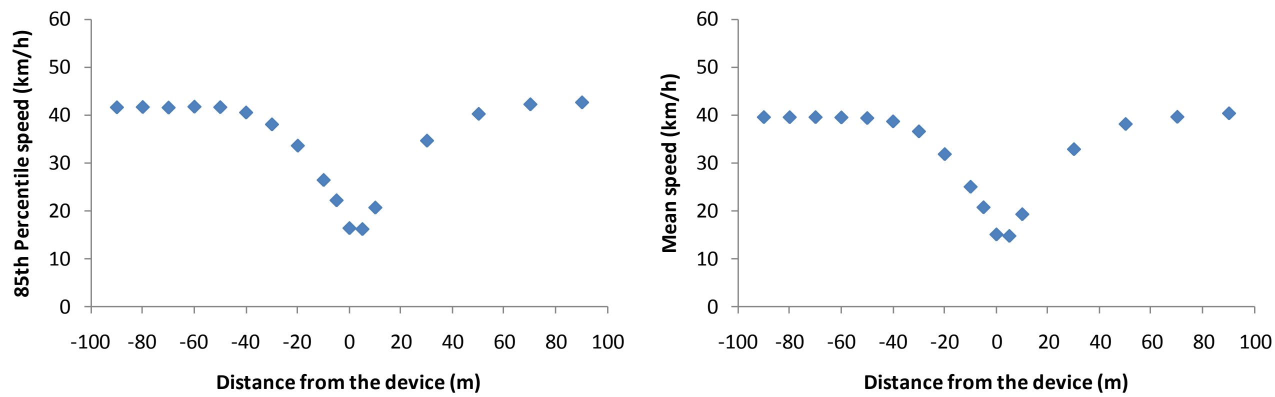

Figure 13 Mean and 85th Percentile speed for Taha Hussein Street northbound direction

9. CONCLUSIONS

The effectiveness of Cat-eye reflectors as traffic calming measure and/or warning device has been assessed in this research through field measurements of speed and in-depth interviews with different drivers. The results show that cat-eye reflectors are not effective in reducing speeds in highways. They are, however, effective in reducing speeds in local roads and suitable for streets with operating speeds of up to 50 km/h. In highway test sites, the average speed was reduced from 67.41 km/h upstream from the device location to 63.56 km/h at the device location, approximately 5.7 percent, and average 85th percentile speed was reduced from 80.43 km/h to 77.79 km/h, approximately 3.3 percent. In local roads, the results show that the average speed was reduced from 44.13 km/h upstream from the device location to 15.6 km/h at the device location, approximately 64.6 percent. The average 85th percentile speeds was reduced from 44.65 km/h to 16.2 km/h, approximately 63.4 percent. The results show that the effect of the cat-eye reflectors is limited to a short range (30 m to 60 m) from the device location.

Results show that Cat-eye reflectors are effective in pavement making and as warning devices in both local roads and highways. They are self-warning as drivers can notice them from far distance. Cat-eye reflectors will not damage vehicles or lead to a loss of control if the drivers pass through them with high speed. Cat-eye reflectors are appropriate devices to mark crosswalks in high pedestrian areas or near school zones. They should be installed approximately 20–30 m upstream from the crosswalk location.

Cat-eye reflectors cost as traffic calming or warning device is reasonable compared to other devices in Egypt. However; the cost benefit of cat-eye reflectors device should be considered because cat-eye reflectors are not cheap in some countries. Level of noise that produced when vehicles traverse cat-eye reflectors depends on configuration and size of cat-eye reflectors and vehicles speed, in residential areas noise impact should be considered.

ACKNOWLEDGEMENTS

Support for this study was provided by Faculty of Engineering, Minia University, Egypt, as a contribution to improve safety in Minia governorate, Egypt.

REFERENCE S

Atkins, C. (1999). "Traffic calming", Transportation planning handbook (2nd edition) Washington, DC' Institute of Transportation Engineers.

Australia Department of Infrastructure (2009). Transport, Regional Development and Local Government. Retrieved 29 June 2009, from research@infrastructure.gov.au.

Brindle, R. (1997). "Traffic calming in Australia - more than neighborhood traffic management", ITE Journal, 67(7), 26–33.

Barbosa, H., Tight, M.R., and May, A.D. (2000). "A model of speed profiles for traffic calmed roads", Transportation Research Part A 34, 103–123.

County Surveyors Society (1994)." Traffic Calming in Practice", Landor Publishing Ltd., London.

City of Portland, Bureau of Traffic Management (1998). "City of Portland speed bump peer review", Portland, OR, USA.

de Wit, T., and Talens, H. (1998). "Traffic calming in The Netherlands", Ede, The Netherlands' CROW.

DfT, Department for Transport (2000). "Village Traffic Calming - Reducing Accidents", Traffic Advisory Leaflet 11/00, UK.

DfT, Department for Transport (2005). "Traffic Calming on Major Roads", UK. Oct 2005.

Duynhoven, H.H. (2005). "Launch of Road Safety Trust Campaign", Retrieved 1 June 2007, from http://www.beehive.govt.nz/ViewDocument.aspx?DocumentID=22225.

Ewing, R. “Traffic Calming State of Practice”, Institute of transportation Engineers. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., August 1999.

Ewing, R. “Traffic Calming Main Roads”, Compendium of Papers for the 79th Annual Meeting of the Transportation Research Board (CD-ROM). Preprint for Transportation Research Board, National Research Council, Washington, D.C., January 2000.

Fildes, B.N., and Lee, S.J. (1993). “The speed review: road environment, behaviour, speed limits, enforcement and crashes”, Report CR127, Federal Office of Road Safety, Road Safety Bureau, Roads and Traffic Authority of New South Wales, Canberra, Australia.

Finch, D.J., Kompfner, P., Lockwood, C.R., and Maycock, G. (1994). “Speed, speed limits and accidents”, TRL Report 58. Crowthorne, UK: Transport Research Laboratory.

Hodge, A.R. (1993). “Speed control humps-A trial at TRL”, Project Report 302. Transport Research Laboratory, UK.

Hallmark, S.L., Peterson, E., Fitzsimmons, E., Hawkins, N., Resler, J., and Welch, T. (2007). “Evaluation of gateway and low-cost traffic-calming treatments for major routes in small rural communities”, CTRE Project 06-185, IHRB Project TR-523. Center for Transportation Research and Education, Iowa State University, US.

Kassem, E., and Al-Nassar, Y. (1982). “Dynamic considerations of speed control humps”, Transportation Research Part B 16, 291–302.

Lockwood, I. M. (1997). “ITE traffic calming definition”, ITE Journal, 67(7), 22–24.

Layfield, R.E., and Parry D.I. (1998). “Traffic calming-Speed cushion schemes”, TRL Report 312. Transport Research Laboratory, UK.

Mak, K.K. (1986). “A further note on undulation as a speed control device”, Transportation Research Record 1061, 13–20.

Miller, N. (2005). “Slow Down Around Roadworks Campaign”, Retrieved 1 June 2007, from http://www.slowdown.co.nz/resources/news 08Mar20052.php.

NRA, National Roads Authority (2005). “Guidelines on Traffic Calming for Towns and Villages on National Routes”, Dublin.

New Zealand Ministry of Transport (2009). “Crash Analysis System”, Ministry of Transport, Wellington, New Zealand.

Oregon Department of Transportation (ODOT) (1999). “Main Street...when a highway runs through it”, A Handbook for Oregon Communities.

Pharaoh, T. M., and Russell, J. E. (1991). "Traffic calming policy and performance", The Netherlands, Denmark and Germany. Town Planning Review, 62(1), 79– 106.

Sumner R., and Baguley C. (1979). "Speed Control Humps on Residential Roads", TRRL Laboratory Report 878. Transport and Road Research Laboratory, UK.

Salusjärvi, M. (1981). "The speed limit experiments on public roads in Finland", Publication 7/1981. Espoo: Technical Research Centre of Finland.

Schlabbach, Klaus (1997). "Traffic Calming in Europe", ITE Journal, 67(7), 38–40.

United Kingdom Department for Transport, 2009. Retrieved 29 June 2009, from ROADACC.STATS@dft.gsi.gov.uk.

Vis, A.A., Dijkstra, A., and Slop, M. (1992). "Safety effects of 30 km/h zones in the Netherlands", Accident Analysis and Prevention 24, 75–86.

Van Schagen, I. (2003). "Traffic Calming Schemes. Opportunities and Implementation Strategies", Report R-2003-22, SWOV. Institute for Road Safety Research, Leidschendam.

Watts G.R. (1973). "Road humps for the control of vehicle speed", TRRL Laboratory Report 597. Transport and Road Research Laboratory, UK.

Webster D.C. (1998). "Traffic calming-public attitude studies: a literature review", TRL Report 311. Transport Research Laboratory, UK.

Webster D.C., and Layfield R.E. (1998). "Traffic Calming-sinusoidal, 'H' and 'S' humps", TRL Report 377. Transport Research Laboratory, UK.