International Journal on Advanced Science Engineering Information Technology

Vol.10 (2020) No. 2
ISSN: 2088-5334

Evaluating the Effectiveness of Road Humps in Reducing Vehicle Speed: Case Study of a University Campus

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***Abstract*— Road humps are designed to control the speed of vehicles through the discomfort that drivers experience when crossing over them. Although the use of various types of road humps in low-speed environments is common, its effectiveness has yet to be seen. This paper evaluated the effectiveness of different types of road humps in reducing the speed of vehicles at a university campus. Field observations were carried out to determine geometric designs of five round-top and five flat-top road humps. All recorded design characteristics of road humps were compared with the standard specifications by various authorities. Only road humps that met any one or more of the standard specifications were considered for speed data collection. Speed data were observed at two selected points during off-peak weekdays and in daylight conditions. A comparison of the observed design characteristics of the road humps with the standard specifications by the authorities showed that most of the humps did not meet any design standard except one round-top road hump and two flat-top road humps. However, only one round-top and one flat-top road humps were considered for further analysis. The average speed of vehicles approaching the road humps was found to be higher than the average speed observed on road humps, with a reduction of 46% and 52% for round-top and flat-top road humps, respectively. The results of statistical analysis also showed that both types of road humps were effective in reducing the speed of vehicles. Thus, it can be concluded that road humps, irrespective of their type, have an impact on vehicle speed.**

***Keywords*— speed; road hump; traffic calming measures; campus area.**

I. INTRODUCTION

Traffic calming is an initiative that uses physical designs and other measures to increase the safety level [1] on the local roads. The measures are intended to make it more difficult for a vehicle to speed or to make the driver feel some discomfort when driving over them at high speeds. They can be implemented whenever the authority that has jurisdiction over the roads or streets believes that they are necessary and appropriate for the situation. Out of the various traffic calming approaches, the road humps are generally implemented in several countries for decreasing the severity and the frequency of the crashes, and for improving the local environment.

Although the speed humps are not considered as official devices for controlling traffic, they are generally used as a geometric pavement design element. The primary design for the speed humps, then known as "traffic control bumps," was invented in 1953. Until the 1970s, there were no significant issues related to the traffic problems in the community areas. However, when the traffic volume increased, the most persistent problems faced by residents were speeding [2], [3], and traffic. Though the local and the residential areas face lesser traffic crashes, they still consume the highest energy and time of a traffic engineer.

Speed humps are raised in pavement areas across a roadway. Various types of road humps are either prefabricated or built on-site, and different designs are often used. Geometric and layout designs must be taken into consideration in order to effectively control the vehicle speed [4]-[8]. The geometric design of speed humps deals with the shape and size of individual road humps. The speed hump design is defined after considering its base length, crown height and the shape of the surface profile [9]. The typical shapes of speed humps are parabolic, flat-top, round-top, or sinusoidal, as illustrated in Fig. 1 [10]. Meanwhile, the layout design of speed humps refers to the determination of the hump spacing and the number of humps to be installed in a section of a road.

In general, the dimensions of speed humps are 7.62-10.16 cm (3-4 inches) high and 3.66-6.71 m (12-22 feet) long. The

Transport and Road Research Laboratory (TRRL) originally developed the speed humps in Great Britain. Earlier studies carried out on the application of the speed humps for controlling the vehicular speed observed that the vertically-rising road pavements were effective and passive devices for calming the traffic, and were used in several Western European and North American countries, during the 1970s [11]. Extensive research on the parabolic road humps revealed that their ideal dimensions were- a length of 3.66 m (12 feet) and a height of 7.62-10.16 cm (3-4 inches). The Australian Road Research Board developed a different speed hump design as compared to the original TRRL design. This design was called the "flat-topped" hump, and its dimensions were-a length of 6.71 m (22 feet) and a height of 7.62-10.16 cm (3-4 inches). In this alternative design, the flat-top region was constructed using brick paving and contained the concrete or asphalt ramps. This was a very aesthetically pleasing design and it also decreased the pavement deformation issues related to the asphalt humps.

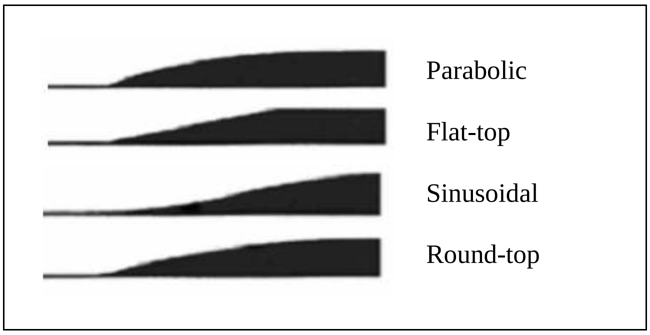


Fig. 1 Common speed hump shapes [10]

Generally, the speed humps are self-imposing, and are referred to as "sleeping police officers." Some studies have shown that road humps are effective in reducing the speed of vehicles traveling through an area, especially at the devices. In typical situations, drivers approaching a speed hump tend to reduce their speed to avoid a bumpy ride, thereby decreasing the chances of speed-related collisions that might otherwise occur and then accelerate after crossing a hump [12]. Previous studies have shown that the mean speed was reduced from between 6-13 km/h before and after the installation of various types of speed humps at different locations [13]-[15]. On the other hand, comparisons of vehicle speeds before and after the installation of speed humps at the 85th percentile speed showed a reduction of between 23% and 28% [16].

In a study carried out in Omaha, Nebraska, out of a sample size of 147 respondents, 82% were in favor of speed humps, stating that they were effective. However, the remaining 18% of the respondents opposed the installation of humps, the reasons being that speeding was still prevalent, the noise level on the streets had increased [17]-[19], fewer parking spaces were available on the streets, and some drivers tended to escape the humps by infringing on the adjacent landscape [20]. Meanwhile, another study in Oxfordshire, England, found that 59% out of 826 respondents were satisfied with the introduction of speed humps, while 35% were dissatisfied. Among those who were dissatisfied were the owners of bus companies, who stated that in addition to the discomfort experienced by their passengers, the maintenance costs for their buses also increased [21]. In a survey study carried out in San Leandro, California, 43% of the 60 residents that lived at 46 m from the speed humps stated that the noise levels had increased. Even though the road humps indirectly had increasingly adverse effects on certain people, these effects were still minor compared to the benefits gained from their installation [22].

This study was aimed at evaluating the effectiveness of road humps in reducing the speed of vehicles in campus areas. Based on the hypothesis, road humps, irrespective of their type, significantly decrease the speed. The remainder of this paper has been divided into three sections. The next section describes the framework of the impact study and data collection, while Section 3 analyses the collected data and the findings of this study. Section 4 presents the conclusions that were drawn from this study.

II. Material and Method

For evaluating the efficacy of the road humps in decreasing vehicular speed, the authors conducted a study on the single-carriageway road sections having flat, straight and right road surfaces within the Universiti Teknologi Malaysia (UTM) campus. UTM is one of the oldest public engineering and technological Malaysian Universities and contains 2 campuses. The main campus has an area of 1,222 hectares and is in the southern region of the Malaysian peninsula, in Skudai, Johor. The second City Campus is 18 hectares and is in Jalan Semarak, Kuala Lumpur. However, for this study, the selected location was at the main campus of UTM, as shown in Fig. 2.

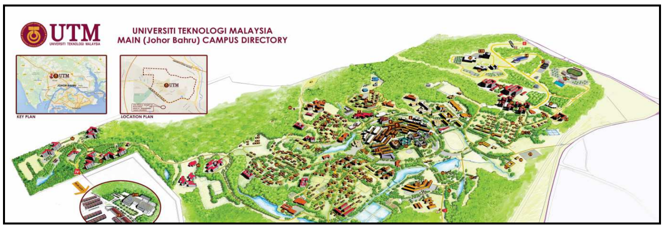
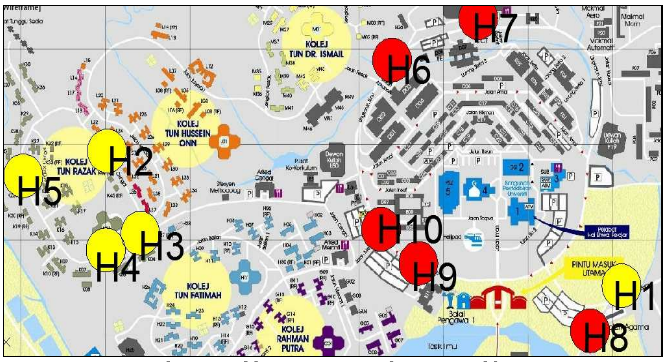


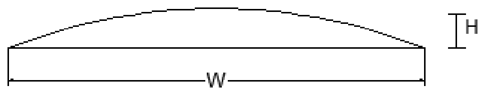
Fig. 2 Universiti Teknologi Malaysia (Main Campus)

The data on the geometric designs of the selected types of road humps and the traffic were collected during daylight and in good weather conditions. The types of road humps that were considered in this study were round-top and flat-top road humps, which had good shapes and were in good condition. As shown in Fig. 3, 10 sites were selected, 4 of which were located at Lingkaran Ilmu, 3 around Kolej Tun Razak, 1 at Jalan Cengal, 1 at Jalan Stadium, and 1 at Lengkok Universiti. Out of all the selected sites, 5 sites had flat-top road humps, and the rest had round-top road humps. For the round-top road humps, the important design characteristics included the width and height of the humps, as illustrated in Fig. 4(a), while for the flat-top road humps, the four main design characteristics, as shown in Fig. 4(b), were the height, slope, base width and top width. In order to present the normal behavior of a driver, the traffic data, mainly the vehicle speed [23] and type of vehicle, were observed when they traversed the observation point during off-peak hours on weekdays from Monday to Wednesday, since the working days in Johor are between Sunday and Thursday. During off-peak hours, there is more likely to be free traffic flow and, consequently, fewer interactions between vehicles [24].

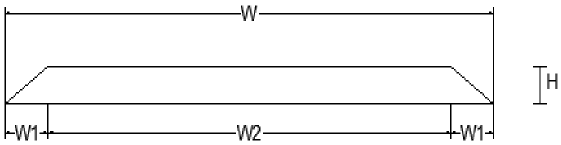


Note: Round-top road hump Flat-top road hump

Fig. 3 Selected sites with round-top and flat-top road humps



(a) Round-top road hump



(b) Flat-top road hump

Fig. 4 Dimensions of road humps

Based on the study objectives, Fig. 5 describes the setup of the various study sites that were used for collecting the traffic data. One cone was placed 50 m before the approaching road hump, and the second cone was placed adjacent to the road hump. The arrow in this figure shows the moving direction of the vehicle. During the traffic data collection, the observer had to be inconspicuous and the equipment had to be concealed from the driver. By using a radar gun, and a cone as a reference point, the speed of the vehicles could be measured when they traversed the cone.

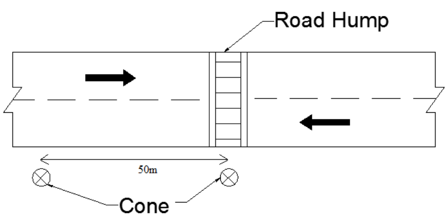


Fig. 5 Layout of study site for traffic data collection

The minimum number of speed data needed for this study was estimated by the Krejcie and Morgan's formula [25] shown in Equation 1 below:

$$S = X^2NP(1-P) / d^2(N-1) + X^2P(1-P) \quad (1)$$

Where, S was the required sample size, $X2$ was the chi-square value obtained from the Table below for a 1-degree of freedom for the required confidence level (3.841), N indicates the population size, while P was the population proportion (it was presumed as 0.50, as this value provided the maximal sample size). Furthermore, d indicates a degree of accuracy which is expressed as the proportion (0.05). Taking into consideration the fact that the main campus of the UTM in Johor, comprised of >20,000 students, the minimal sample size for every site was 377.

In this study, all the recorded design characteristics of road humps were compared with the standard specifications by various authorities like SIRIM [26], Majlis Bandaraya Johor Bahru (MBJB) [27], the Highway Planning Unit (HPU) [28], and Majlis Perbandaran Seberang Perai (MPSP) [29], as presented in Tables I and II. This comparison was important to determine which standard specifications were used for the installation of the road humps on the main campus of UTM due to variation in existing hump dimensions [17]. Only road humps that met any one or more of the standard specifications were considered for the speed data collection.

TABLE I
STANDARD SPECIFICATIONS FOR ROUND TOP HUMP

	Height (H) mm	**Width (W) mm**
SIRIM [26]	75 - 100	3700 – 4250
MBJB [27]	100	3700 – 5400
HPU [28]	50 - 100	3700 – 4000
MPSP [29]	100 - 150	3000

TABLE II
STANDARD SPECIFICATIONS FOR FLAT TOP HUMP

	Height mm	**Width mm**			**Slope**
	(H)	**W**	**W1**	**W2**	
SIRIM [26]	75 - 100	3700 - 4250	-	-	-
MBJB [27]	100	-	1500	6000 - 10000	1 :8 – 1 :15
HPU [28]	75 - 100	-	4000	2500	-
MPSP [29]	80 - 150	3000	-	-	1 :8 – 1 :15

Then, any recorded data representing vehicles that started or stopped within the selected section, vehicles whose behavior was affected by pedestrians, cyclists or animals, and vehicles in conflict with opposing vehicles were removed to ensure that all the data were valid. The recorded speed data were analyzed to observe the speed distribution and to determine the 85th percentile speed which was considered as the driver's choice of speed before and on the road hump. The average speed was also calculated at two selected points (when approaching and when on the road humps) at each site. Lastly, the effectiveness of the road humps in reducing speed was determined based on statistical analysis.

III. Results and Discussion

A. Road Hump Design Characteristics

Tables III and IV show the summary of the comparison between the observed design characteristics of the road humps and the standard specifications for round-top and flat-top road humps. Based on the results, it was found that most of the road humps at the sites on the main campus of UTM do not follow any design standard. According to the Malaysian Ministry of Road Works [30], if road humps are not constructed following the guidelines and do not have a standard design, the place will have the same devices but with different dimensions. However, there are still some sites that have installed road humps according to the standard specifications provided by the authorities. For the round-top road humps, it was found that H1 met the criteria given in all the standard specifications, except for those by the MPSP. However, under the category of flat-top road humps, H6 and H10 were found to follow the standard specifications provided by SIRIM. However, in this study, only H1 and H6, as shown in Fig. 6, were further studied to determine the effectiveness of different types of road humps in reducing speed.

TABLE III
COMPARISON OF DESIGN CHARACTERISTICS FOR ROUND TOP ROAD HUMPS

Site	SIRIM [26]	
	Height (H) mm	**Width (W) mm**
H1	√	√
H2	√	S
H3	L	S
H4	√	S
H5	√	S
Site	**MBJB [27]**	
	Height (H) mm	**Width (W) mm**
H1	√	√
H2	√	S
H3	L	S
H4	√	S
H5	√	S
Site	**HPU [28]**	
	Height (H) mm	**Width (W) mm**
H1	√	√
H2	√	S
H3	L	S
H4	√	S
H5	√	S
Site	**MPSP [29]**	
	Height (H) mm	**Width (W) mm**
H1	√	L
H2	√	L
H3	√	L
H4	√	L
H5	√	L

Note: √ = Follows the standard; S = Shorter than standard; and L = Longer than standard.

TABLE IV
COMPARISON OF DESIGN CHARACTERISTICS FOR FLAT TOP ROAD HUMPS

Site	SIRIM [26]	
	Height (H) mm	**Width (W) mm**
H6	√	√
H7	L	√
H8	√	L
H9	L	L
H10	√	√

Site	MBJB [27]			
	Slope	**Height (H) mm**	**Width (W1) mm**	**(W2)**
H6	LS	√	S	S
H7	√	L	S	S
H8	√	S	√	S
H9	√	L	L	S
H10	√	S	S	S

Site	HPU [28]		
	Height (H) mm	**Width (W1) mm**	**(W2)**
H6	√	S	S
H7	L	S	S
H8	√	S	L
H9	L	S	L
H10	√	S	S

Site	MPSP [29]		
	Slope	**Height (H) mm**	**Width (W2) mm**
H6	LS	√	S
H7	√	√	S
H8	√	S	S
H9	√	√	S
H10	√	S	S

Note: / = Follows the standard; S = Shorter than standard; L = Longer than standard; and LS = Less steep.

(a) Site H1

(b) Site H6

Fig. 6 Selected humps for traffic survey

B. Driver's Choice of Speed Before and on Road Hump

Fig. 7 and Fig. 8 present the speed distribution 50 m on approaching the round-top road hump at H1, and the flat-top road hump at H6, respectively. Among the 378 vehicles that were sampled for each site, it was found that 22.2% of the vehicles were being driven below the posted speed limit of 35 km/h at site H1, and this was slightly higher than the percentage shown for the flat-top road hump at H6. On the other hand, it was found that around 36.0% of the vehicles were being driven between 35 and 39 km/h at both sites. It could also be seen from these figures that 1-3% of the vehicles were captured being driven at more than 50 km/h at 50m before the road hump. This was dangerous for the surrounding environment because there is a high number of pedestrians in the campus area, especially at H1, where there is a school for children aged between 7 and 12 years.

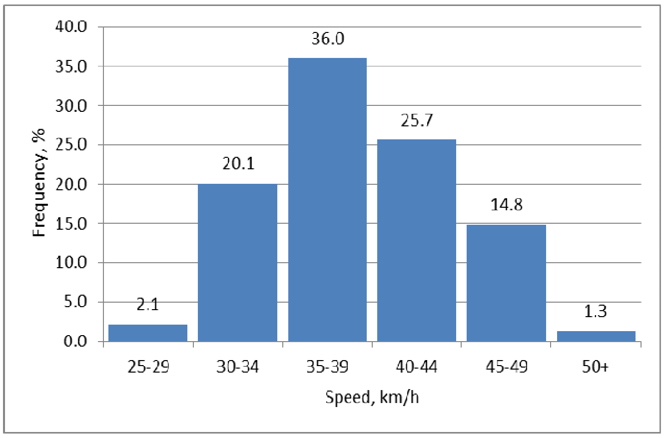


Fig. 7 Speed distribution before approaching round-top road hump at H1

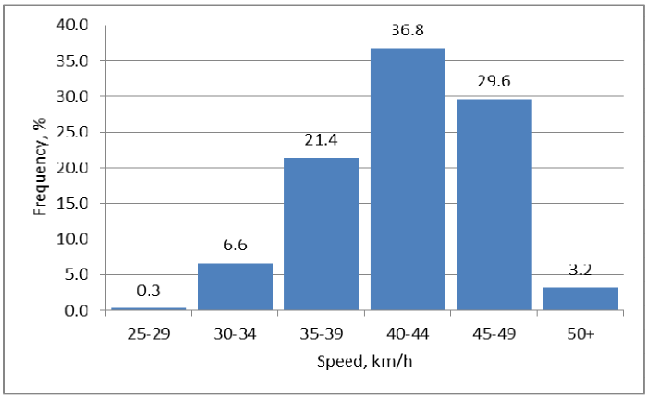


Fig. 8 Speed distribution before approaching flat-top road hump at H6

As illustrated in Fig. 9 and Fig. 10, the curves for both types of road humps demonstrated that the speed distributions had normal-like curves. The results for the round-top road hump at H1, indicated that the 85th percentile speed of the vehicle approaching the road hump was around 45 km/h, while for the flat-top road hump, it was 47 km/h. Thus, it was clear that most of the car drivers at UTM drove at more than the posted speed limit without the influence of the road hump. However, the vehicle speed tended to reduce to approximately 27 km/h and 25 km/h for the round-top and flat-top road humps, respectively when measured at the 85th percentile. These results indicated that many of the drivers reduced the speed of their vehicles below the posted speed limit that was considered as being safe for pedestrians in the campus area.

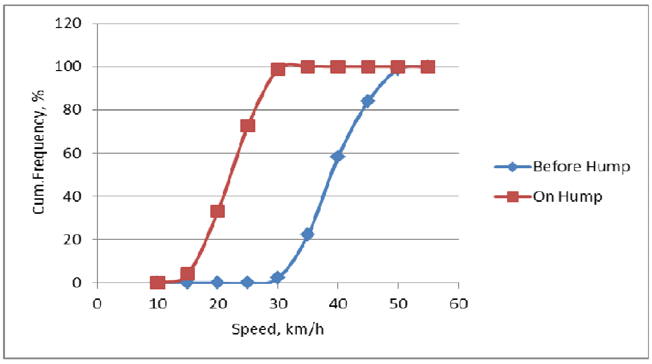


Fig. 9 Cumulative speed distribution for round-top road hump at H1

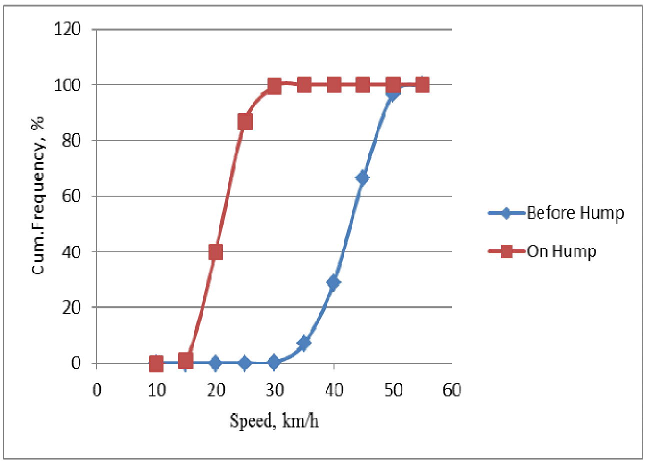


Fig. 10 Cumulative speed distribution for flat-top road hump at H6

C. Effectiveness of Road Humps in Reducing Speed

Table V presents the descriptive statistics of the speeds at two selected sites, H1 and H6. The mean speed on approaching both types of road humps was found to be higher than on the road humps. The finding showed that the average speed before approaching the road humps was more than the posted speed limit and that due to the presence of the road humps, the average speed was reduced to below the posted speed limit. Based on the analysis, the reduction in mean speed for the round-top road hump was around 46%, while for the flat-top road hump, it was around 52%. The standard deviation for the speed on approaching the road hump was around 5 km/h, while for the speed on the road hump, the standard deviation was approximately 3 km/h.

TABLE V
DESCRIPTIVE STATISTICS OF SPEED DATA

(a) Round-top road hump at H1

Location	Sample Size (veh)	Mean Speed (km/h)	Std. Deviation (km/h)
Before hump	378	38.7	5.3
On hump	378	21.5	4.0

(b) Flat-top road hump at H6

Location	Sample Size (veh)	Mean Speed (km/h)	Std. Deviation (km/h)
Before hump	378	42.0	5.4
On hump	378	20.6	3.4

A t-test was performed to assess the statistical significance of the difference in the mean speeds between the two selected points (approaching and on the road hump). The results of the t-test at a confidence level of 95% for the round-top road hump at H1 and the flat-top road hump at H6, as shown in Table VI, suggested that the difference in the mean speeds for both types of road humps was statistically significant. Therefore, the findings clearly showed that well-designed road humps are effective at reducing speeds on local roads at the main campus area of UTM.

TABLE VI
T-TEST FOR MEAN SPEED REDUCTION DUE TO ROAD HUMP

Site	Reduction in Mean Speed (km/h)	t-value	p-value
H1	17.2	50.447	0.000
H6	21.4	65.137	0.000

IV. CONCLUSION

Based on a synthesis of the empirical evidence from the road hump impact study carried out single-carriageway roads at the main campus of UTM in Skudai town, Malaysia, it can be concluded that most of the humps installed at the main campus of UTM do not meet any design standards. However, road humps that are properly installed can effectively reduce vehicle speed by 46% for round-top road humps and by 52% for flat-top road humps. Finally, the hypothesis that road humps, irrespective of their type, can reduce vehicle speed significantly, is valid.

ACKNOWLEDGMENT

The authors would like to express their deep gratitude to the Ministry of Higher Education, Malaysia and Universiti Teknologi Malaysia for providing the financial grant (Ref: FRGS/1/2016/TK08/UTM/02/2, Cost Centre No.: R.J130000.7822.4F867) and opportunity to carry out this research.

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