Malaysian
Journal Of Civil
Engineering

THE IMPACT OF UNEVEN JOINT OF BRIDGE APPROACH SLAB AND DECK TO ROAD USERS PERCEPTION AND SPEED: A CASE STUDY IN JAMBATAN PARIT JAMIL AND JAMBATAN PARIT HAJI IBRAHIM, JOHOR

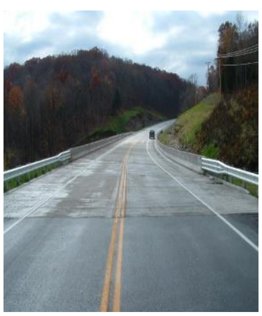
Article history
Received
29 March 2021
Received in revised form
02 August 2022
Accepted
04 August 2022
Published online
30 November 2022

Nasradeen A. Khalifa[a], Mohd Hanifi Othman[a*], Muhammad Irfan Kamarudin[b], Noorliyana Omar[a]

[a]Smart Driving Research Centre, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[b]Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

*Corresponding author
hanifi@uthm.edu.my

Graphical abstract



Abstract

Bridge approaches offered a smooth and safe transition for any vehicle from the road pavement to the bridge structure and vice versa. Settlement of the soil that occurred at the joint of bridge approach slab and deck of Jambatan Parit Jamil results in a slight change of their level which can create a 'bump' on the roadway. This uneven joint occurs due to soil settlement under the bridge approach due to the increasing number of rough rides by the driver that cause cracking at the approach slab. Thus, the 'bump' or uneven joint between the bridge deck and road pavement will cause driver discomfort, impair driver safety, reduce steering response, and increase the expense for maintenance operation. The purpose of this study is to investigate the perception of the respondents about the shock impact and to evaluate their speed reduction during maneuvering the uneven joint of the approach slab and the bridge deck. Thus, a social survey has been conducted in Kampung Parit Jamil and Kampung Parit Penyengat to investigate the perception of frequent road users about uneven joints. The spot speed study method has been used to evaluate vehicle speed reduction in maneuvering the uneven joint. The speed reduction results were then compared with the speed of vehicles on a good condition bridge as a control sample. The results show that most of the respondents suggest that they are 'very disturbed' (70%) with uneven joint. The speed reduction on the uneven joint bridge recorded 13km/h mean speed readings of 13 km / h and possess 5km/h differences with a good condition bridge. The results are expected to highlight the impact of uneven joint issue on road users' comfort and traffic speed.

Keywords: uneven joint, discomfort, speed reduction, bridge approach, traffic speed

1.0 INTRODUCTION

There are many types of bridge in Malaysia that were used frequently by road users in rural or urban roads. These types of bridge serve different purpose depending on several situations such as type of load, material used, and structural elements used. Beam bridges are the most common bridges that have been used in highway overpasses. This bridge is generally supported by an abutment or pier at each end that consists of one or more spans. The loads applied towards the beam bridge undergo horizontal compression at the top, while horizontal tension subjected to the bottom of the beam (Lall et al., 1998).

Beam bridges are generally made of reinforced concrete or metals. Beam bridges in Malaysia are commonly used for rural roads, especially for cross valley (Masirin & Zain, 2013). Normally the bridge deck is constructed depending on the traffic load and other characteristics. The increasing number of traffic loads that use the bridge will decrease the endurance of the bridge.

The construction of a bridge and road pavement under soft soil always results in a differential settlement problem between the joint of the approach slab and the bridge deck. From time to time, the soil settlement problem for the soil causes uneven joint between the bridge deck and the pavement. Settlement may be noticeable when there is a slight change in the level of the joint of approach slab level and end of the paved roadway (Saride et al., 2009). These settlement- and heave-related movements of bridge approach slabs relative to bridge decks usually create a bump in the roadway (Cai et al., 2005). From field observation, the fault near the slab and pavement causes this bump (Mohamad et al., 2016).

The uneven joint in Jambatan Parit Jamil creates inconvenience for road users, distracts the driver, decreases the public image of the transportation agency, reduces steering control, and increases maintenance operations expenses. Other than that, the unevenness caused shock impact to vehicles when passing on it. The shock impact may irritate road users. In addition, road users may also face delays because they have to slow down their vehicle when approaching the bridge and during lane closing for maintenance and repair.

This research was carried out to investigate the perception of respondents about shock impact during crossing the uneven joint between the approach slab and the bridge deck. Furthermore, this study aims to evaluate the speed of traffic during uneven joint maneuver. The study was carried out at Jambatan Parit Jamil. There is one particular bridge at coordinate (1°56'29.8"N 102°39'31.8"E) that was the focus in this study. This bridge crosses the trench at Parit Jamil. Road users who lived nearby become respondents to the survey. The respondents can come from a random sample from age 17 to 60 years or older. In addition, the use of survey form is the medium to evaluate the perception of the respondent towards the problem that occurs at the bridge. All information from the survey forms was collected to be analysed. In addition, a spot speed study was conducted to determine the reduction of the vehicle speed toward the problem. All collected data were recorded into a table to be analysed. This study provides insight into knowledge about the driving behaviour of road users. In addition, with the survey, the level of disturbance faced by road users was measured. In addition to that, the spot speed study that was conducted was able to determine the reduced speed of the vehicle during maneuvering the uneven joint of the bridge. The spot speed study method has been used to evaluate vehicle speed reduction when maneuvering the uneven joint. The results of the speed reduction were then compared with the speed of vehicles of vehicles on a good condition bridge as a control sample.

Although excessive settlement on a bridge approach is easy to spot, its causes are often complex. Figure 1 illustrates a typical slab approach configuration used in bridge construction. The slab is usually supported on a back wall at one end and on the adjoining highway embankment at the other. The bump that is often felt while driving over an approach slab reveals a differential settlement of an embankment relative to the superstructure. In most situations, the greatest concerns include deterioration of ride quality and impaired driver control of a vehicle. In extreme cases, the resulting impact traffic load may adversely affect the useful life of a structure.

With reference to Figure 1, it is evident that a finite amount of differential settlement is inevitable in virtually all bridge approaches. The bridge is typically constructed with deep foundations designed to prevent negligible settlement of the abutment. On the other hand, the adjoining approach embankment is built incrementally with numerous layers of fill material, which can settle appreciably if not properly placed and compacted. Furthermore, the underlying subsurface soils can undergo significant settlement due to consolidation caused by the weight exerted by the approach embankment. The consolidation component is often predominant in areas underlain by soft clays and silts. Other common contributions to the settlement of the fill stem from erosion of embankments and the movements of the thermal bridges.

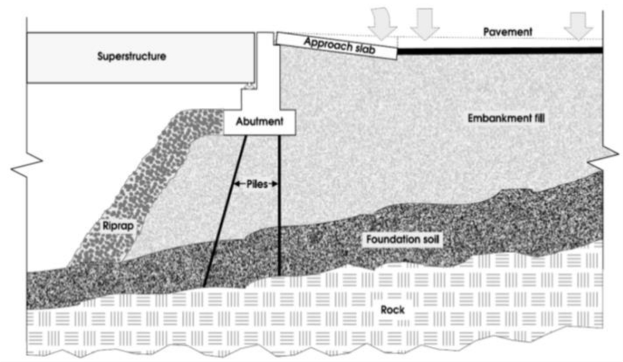


Figure 1 Bridge Approach Settlement

2.0 APPROACH SLAB

Approach slabs that are reinforced concrete slabs used to provide smooth transition between the bridge deck and the road pavement as 80 percent of the new bridge used this system during bridge construction of bridge (Saride et al., 2009). The approach slabs that are used to support at both ends of the bridge usually have a thickness of about 23 to 30 cm with 6 to 12 m long, while the width is the same length as bridge deck. In addition, the end of the bridge also uses abutment as a support to withstand the load that is applied towards the bridge. The pavement end is usually supported by a sleeper slab or directly by the roadway embankment (Attanayake & Aktan, 2006). Sleeper slab is the slab that support the adjacent road pavement and is used to support the end of approach slab. The approach slab at Jambatan Parit Jamil is shown in Figure 2.

Figure 2 Approach slab at Jambatan Parit Jamil

3.0 SETTLEMENT SOIL OF ROAD

Parit Jamil is an area located in Johor, Muar, Malaysia. The increasing number of economic activities has encouraged the increase of the number of new infrastructure development. As a result, the number of vehicles that use the main road connecting Parit Jamil to another district has increased. Apparently, this area is located in a wetland region of which there is a significant traverse soft soil deposited of marine or coastal alluvium (Saride et al., 2009). The construction of a bridge and road pavement under soft soil always results in a differential settlement problem between the joint of the approach slab and the bridge deck. The fault and the change in slope occurred in Jambatan Parit Jamil due to settlement of embankment as shown in Figure 3. This problem occurred due to nonuniform and excessive consolidation settlement.

Figure 3 Settlement problem in Jambatan Parit Jamil

Settlement can be defined as the deformation of the soil due to the applied load and the stress that is exerted on it (Mohamad *et al*., 2016). Normally, soft organic soil is not capable of carrying the load that a structure exerts because it has a high field moisture content that can be as much as 800% at times (Asadi A. *et al.*, 2013).

4.0 LOCATION OF CASE STUDY

There are two locations that have been selected as a case study. Both of the bridges named Jambatan Parit Jamil and Jambatan Parit Haji Ibrahim, which are located at Muar, Johor. The location selected based on differences in elevation of the uneven joint. The elevation of the uneven joint had been measured to determine which location became the case study bridge and the control sample bridge. In addition, these two locations are also being selected through the observation at both bridges.

Jambatan Parit Jamil is one of the bridge in Federal Road 05 that connecting Muar and Batu Pahat town. This bridge is made up of 33 m length and 25 m width. From Figure 4, the elevation of the uneven joint for this bridge is 2.2 cm, which is quite high and could cause discomfort for the driver when crossing this bridge. Apparently, this area is located at wetland region that has significant soft soils such as clay and peat soils. The bridge is heavily used by the vehicle to travel to Bandar Muar and Batu Pahat. Road users who live in a nearby area would be selected as respondents for this study. This bridge has several issues with the uneven joint on the bridge approach between the road and the bridge deck. The settlement was measured to be around 2.0-2.5 cm.

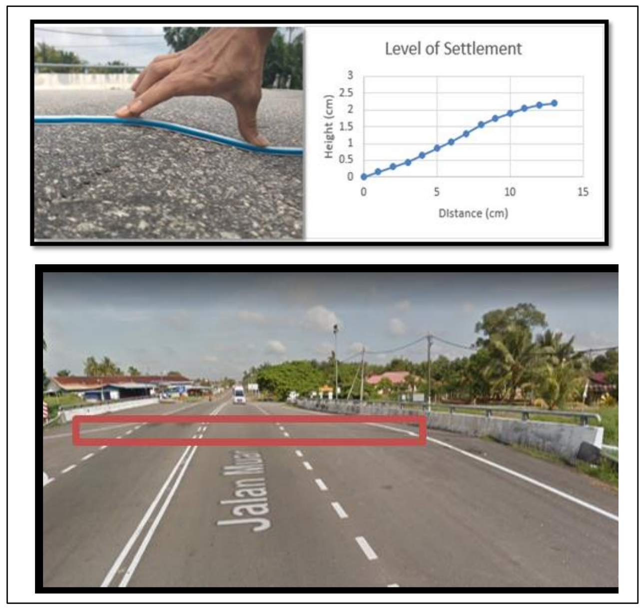


Figure 4 Elevation of uneven joint in Jambatan Parit Jamil

Jambatan Parit Haji Ibrahim is located in Johor, Batu Pahat, Malaysia. This bridge is 13 m wide with 15 m length. The elevation between the bridge deck and the approach slab is 0.5 cm as indicated in Figure 5. This bridge had been selected as the control sample bridge because the uneven joint was less than the case study bridge in Jambatan Parit Jamil. In addition, the design of the road is straight for both bridges making Jambatan Parit Haji Ibrahim the control sample bridge. Other than that, both bridges were made up of two-way road lane, which affected the factor of this bridge selected as the control sample bridge. From the observation, the vehicles that used this road seem to be not distracted towards the uneven joint of the bridge. Most of the vehicles speeding on this bridge

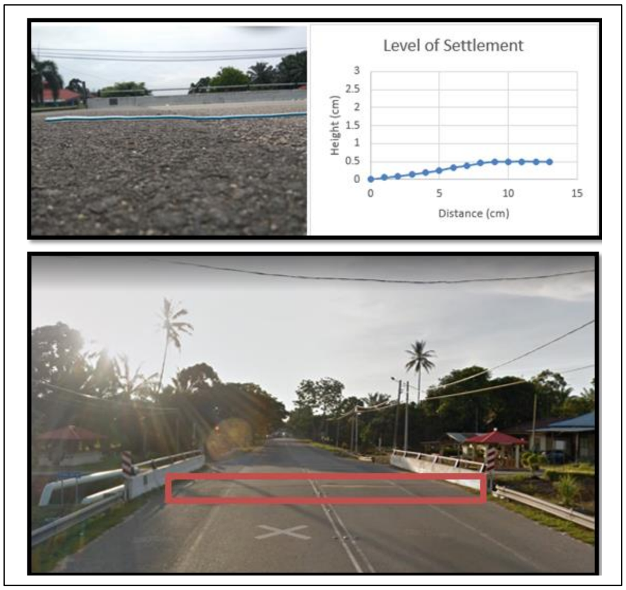


Figure 5 Elevation of uneven joint at Jambatan Parit Haji Ibrahim

4.1 Perception Of Road Users Towards Shock Impact Due To The Uneven Joint

The perception of road users towards the impact of the shock impact was evaluated using the social survey method. There are several steps to conduct this social survey, such as preparation of the questionnaire, pilot study, distribution of the questionnaire, and analysis of data. This questionnaire consists of two parts, which are Part A and Part B. In Part A the question was about the background of the respondent, while Part B is about the response of the road user's response based on the uneven joint in the bridge approach between road and the bridge deck.

This survey uses the Likert scale method where the respondents may be offered a choice of five to seven, or even nine preceded responses to allow everyone to express how much they agree or disagree with a particular statement. In addition, this survey consists of a Yes or No question to expose your response about the problem that occurs at the bridge. In addition to that, a multiple-choice question is also provided in this questionnaire. After the data had been collected from the survey, the data were analysed based on the scale, the level of discomfort was measured through the 1 to 5 scale as level 1 for not disturbed at all, level 2 as not disturbed, level 3 for neutral, level 4 for disturbed while level 5 for very disturbed. A set of questionnaires were distributed to residents and public that live nearby Jambatan Parit Jamil and Jambatan Parit Haji Ibrahim. There are 30 people who come from any background who are the respondents in this survey. As a result, 83%, which represents 25 males participate in this survey compared to female with only 17%. The least number of female respondents affect by the researcher gender as make the respondent find difficulty to get approach by other gender for a cooperation. It was found that 33% of the villagers within the range of 31 to 35 years old became respondents. Then, it followed by the age of 41 to 45 years old and 46 to 50 years old which share same percentage of respondents with 17%. Awareness of the impact during manoeuvring bridge will be different depending on the maturity of the drivers. There is no respondent from the age of 15 to 20 years old

4.2 Traffic Speed Reduction In Uneven Joint

The reduction in vehicle speed was evaluated by using a spot speed study. There are three instruments used in this study which are an odometer that is used to measure the length of the road followed by a Radar gun meter that is used as the vehicle measurement speed and a cone was used to refer point for the vehicle and the travel between the start to end point. The data had been collected at three-point locations at each bridge that are 81 m before joint of bridge for the first point, followed by the second point at joint of the bridge and the third point located on the bridge. The layout of all three reference point locations is shown in Figure 6. Next, the data are compared with the control sample bridge that has the uneven joint difference elevation of the uneven joint to determine the difference in speed reduction.

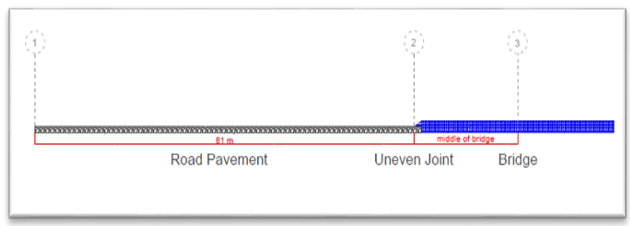


Figure 6 Location of the reference point

The speed data obtained are tabulated into a table to be analysed. Appendix C shows an example of tabulation of data obtained from field. From the data obtained, the result will be presented in a few graphical methods. The graphical method that was used is the frequency distribution table, the frequency histogram diagram, and the cumulative frequency distribution curve. The two important characteristics of a distribution are the measure of central tendency and the dispersion of the distribution. The central tendency described the approximate centre of a distribution. These central tendencies include the pace, mean, median, and modal speed. The pace is only used in traffic engineering as it represents a 10km/h range between the highest values of speed limit in the frequency distribution table. The 10km/h is the range between the frequencies that gives the highest percentage of vehicles. The mean is the average value that constitutes the central tendency.

5.0 PREVIOUS STUDIES ON EFFECT SPEED HUMPS TO TRAFFIC

Several studies have been conducted on this issue. Most of the previous research state that the speed of the vehicle is reduced when approaching road humps and increases after leaving road humps. (Syazwani et al., 2016) had conducted research on the effect of road humps in reducing speed along the local road of the residential area in Taman Setiawangsa. Road humps are considered as a speed reduction towards vehicles in the residential area. However, the installation of road humps also contributes to undesirable effects towards the surrounding environment such as increasing air and noise pollution due to sudden and frequent acceleration and deceleration of vehicles. The average speed of the cars at each point varies from one another. Table 1 shows that the average speed of cars 30 meters before Road Hump 1 was 59.93 kmh while that 30 meters after Road Hump 2 was 41.27 kmh. At Road Hump 1, the average speed was 4.63 kmh, while at Road Hump 2 it was 4.2 kmh. Furthermore, the average speed of the cars between the road humps was 42.5 kmh. The decrease in speed at the road humps shows a difference of 55.3km/h between the first point at 30 meters before Road Hump 1.

Table 1 Measures of central tension

Central Tendency	Mean Speed (km/h)	Modal Speed (km/h)	Median Speed(km/h)
30m before Road Hump 1	59.93	72.5	60
At Road Hump 1	4.63	4.5	4.56
Between Road Hmpa 1 & 2	42.5	42.5	44
At road Hump 2	4.2	4.5	4.15
30m after Road Hump 2	41.27	42.5	41.6

6.0 RESULTS AND DISCUSSIONS

The uneven joint seems to be a common problem in all bridges on the road bridge, but it was being distraction toward the traffic users. The effect to traffic users depends on the elevation of the uneven joint, as the increasing elevation of the uneven joint gives different reaction and speed reductions to traffic users in maneuvering the bridge. Data on the level of discomfort and impact on the driver during crossing the bridge had been collected from the social survey.

6.1 Respondent

According to Figure 7, all respondents agree that uneven joints in Jambatan Parit Jamil cause inconvenience and discomfort to them, since 100% of them choose yes as their answer. The result is expected to be obtained from this survey, as many vehicles reduce the speed when approaching the uneven joint at this bridge. The change in elevation of the joint influences the impact of the vehicle when passing through it. From this survey, the respondents feel annoyed with the impact of having to slow down their vehicle, whereas they are in a hurry. As a result, there are no respondents not affected by the impact of the uneven joint.

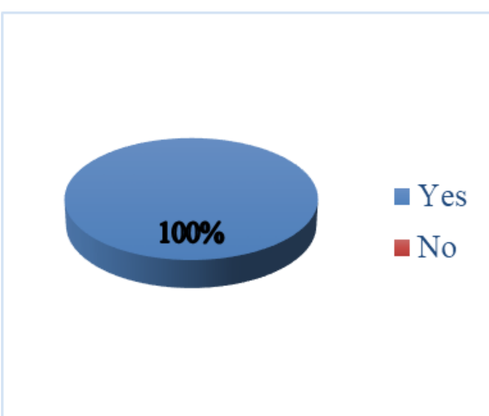


Figure 7 Discomfort during uneven joint on the bridge

The level of discomfort that respondents experience when passing through uneven joints is recorded in the bar chart as shown in Figure 8(a). Most of the respondents, with 20 respondents feel that uneven joint has very disturbed them, as they create bumps that can affect the reduction in steering control. The situation will create danger to other drivers as accidents can occur when the vehicle loses control. Figure 8(b) shows the driving behaviour through impact when maneuvering the uneven joint. There are 21 respondents, and 70% from all the respondents are very disturbed with the impact of the uneven joint. The huge impact that is produced from the uneven joint affects their driving behaviour, as they have to reduce their speed and focus on their steering control to prevent their vehicle from losing control.

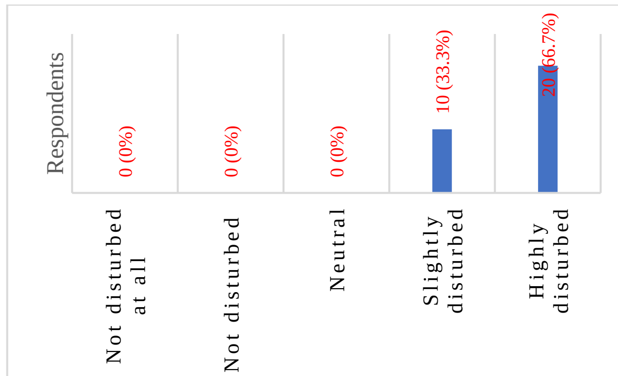


Figure 8(a) Level of discomfort during manoeuvring uneven joint on the bridge

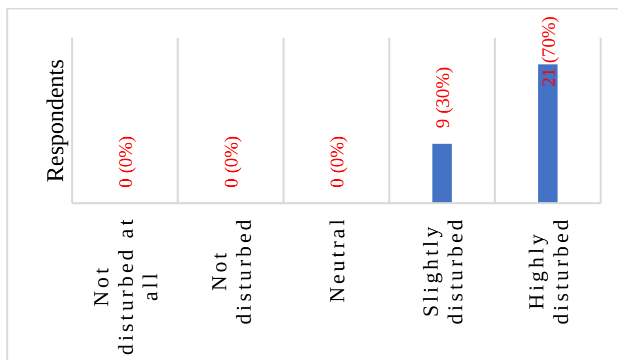


Figure 8(b) Impact of road users driving behaviour

Figure 9(a) shows the estimate of speed from the respondents when maneuvering an uneven joint of the bridge. 57% of the respondents choose to drive in the speed range between 31 and 40km/h. The range of speed is considered safe speed because the uneven joints can cause huge impact if there is no reduction in speed during maneuvering the bridge. According to the respondent, by slowing down the speed of the vehicle, the impact towards the driver can be reduced and prevent inconvenience towards them. There is no other speed that the respondent chooses as they feel that the safe speed to maneuvering the uneven joint is between 20km/h to 50km/h.
Based on Figure 9(b), there 43% that consists of 13 respondents choose to drive within the speed of 71 to 80km/h if on the bridge without uneven joint. While 37% that consists of 11 respondents

tend to drive within the speed from 81 to 90km/h. Most of the respondents tend to drive at higher speed at the bridge without uneven joint because there is no distraction for the driver and reduction in steering control. As a result, they do not have to reduce the speed of the vehicle and drive comfortably as usual.

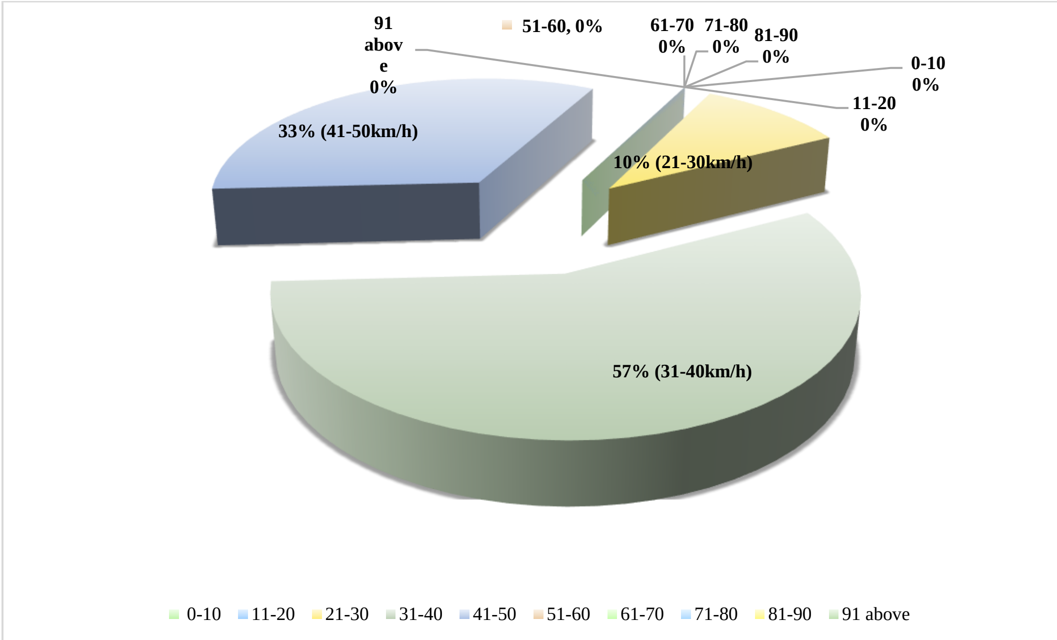


Figure 9(a) Speed during the uneven joint of the bridge.

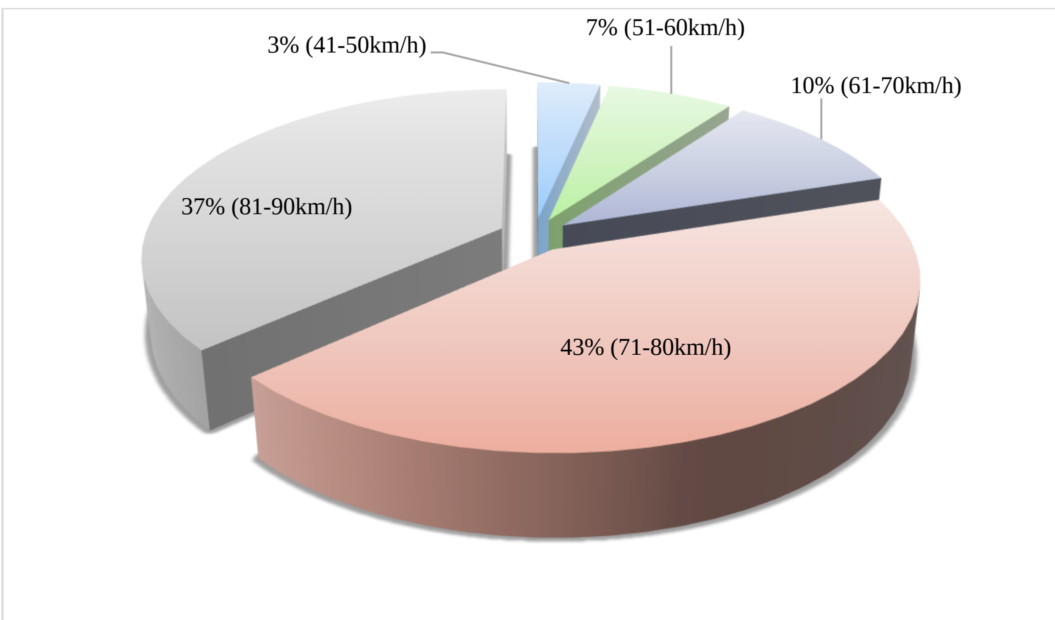


Figure 9(b) Speed during the uneven joint of the bridge without uneven joint.

6.2 Speed Analysis Data

The average speed of the vehicles at each point varies between one another. The mean speed at Jambatan Parit Jamil for the first point is 69.77 km/h, while the mean speed for the second point is 56.84km/h. Road users tend to slow down their speed vehicle to reduce impact during maneuvering uneven joint of the bridge joint. The mean speed for the third point is 44.36km/h. The average speed at Jambatan Parit Haji Ibrahim shows different flow compared to the previous bridge. The mean speed for the first point is 61.37km/h, while the mean speed for the second point is 58.22km/h. The mean speed for the third point is 56.67km/h Table 2.

Table 2: Measures of Central Tendency

Central Tendency	Jambatan Parit Jamil		Jambatan Parit Haji Ibrahim	
	Mean Speed (km/h)	Modal Speed (km/h)	Mean Speed (km/h)	Modal Speed (km/h)
81 m before uneven joint.	69.77	65.5	61.37	55.5
At the uneven joint	56.84	55.5	58.22	55.5
At the middle of bridge	44.36	45.5	56.67	55.5

The comparison of the mean speed on two different bridges is shown in Figure 10. The mean speed at the first point shows that the vehicle speed at 81m before Jambatan Parit Jamil is higher than Jambatan Parit Haji Ibrahim. The difference in elevation of the uneven joint cause the speed reduction at Parit Jamil higher than that of Parit Haji Ibrahim as the vehicle slows down the speed to reduce the impact when maneuvering the uneven joint. The difference in mean speed from first point to the second point at Parit Haji Ibrahim is only 3 km/h, while at Parit Jamil the difference is 13km/h. The result shows that the higher the elevation of the uneven joint, the higher the speed reduction. Finally, the mean speed at third point, located after the uneven joint at the middle of the bridge, shows the speed at Parit Jamil to reduce about 12km/h from the second point to become 44.36km/h. The difference situation occurred at Parit Haji Ibrahim as the speed reduce only 2km/h from second point until become 56.67km/h. The huge reduction in speed that occurred at Parit Jamil was caused by the perception of road users that the uneven joint at the opposite end of the bridge would give the same impact on them.

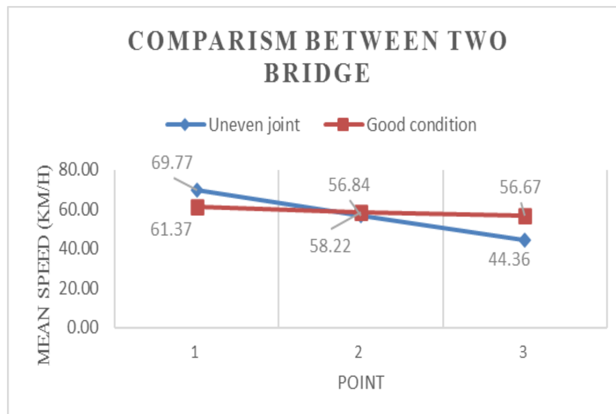


Figure 10 Speed reduction at each point on a different bridge

The 85th percentile speed Table 3, in Jambatan Parit Jamil and Parit Haji Ibrahim. The table shows that 85% of vehicles were moving at a speed of 75 km/h at 80m before reaching the bridge joint, 60 km/h at the joint and 46km/h at the middle of the bridge. The median speed for the three points is 40km/h at 81m before the joint, 51.5km/h at the joint and 63km/h at the middle on the bridge. The 15th percentile for the first point is 56km/h, while 44km/h at the second point is followed by 32km/h at the third point. Consequently, the speed of the vehicles is within the speed limit as the 85th percentile value below than the allowable speed limit of the state roa

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Table 3 85th, 15th, and 50th percentile

Central Tendency	Jambatan Parit Jamil			Jambatan Parit Haji Ibrahim		
	85^{th} percentile (km/h)	Median speed (km/h)	15^{th} Percentile (km/h)	Mean Speed (km/h)	Median Speed (km/h)	15^{th} Percentile (km/h)
81 m before uneven joint.	75	40	56	68.5	55	46
At the uneven joint	60	51.5	44	64	52.5	42
At the middle of bridge	46	63	32	62	51.5	40

The difference in speed before and at the uneven joint (Pair 1) and the at the uneven joint and middle of the bridge (Pair 2) was tested for statistical significance using the t test. The results at Jambatan Parit Jamil show that both tests were statistically significant in a 95% confidence interval Table 4. The finding shows that there was a significant difference in the speed of vehicles for both pairs. If the t statistic is larger than the critical two-tail value, H_o would be rejected. Since 16.26 is larger than 1.96 in pair 1, H_o was rejected. If the p-value is smaller than α, H_o would be rejected. Since the p-value of 1.07 x 10-47 is smaller than α=0.05, the Ho was rejected. There is enough evidence to conclude that the speed reduction occurred when the vehicle maneuvered in an uneven joint. In pair 2, since 18.28 is larger than 1.96, Ho was rejected. Furthermore, the p-value 3.59 x 10-47 is smaller than α=0.05, the Ho was rejected. There is enough evidence to conclude that reduction in speed occurred when vehicle maneuvers unevenly.

Table 4 Sample statistic for vehicle speed

	Pair 1		Pair 2	
	First Point	**Second Point**	**Second Point**	**Third Point**
Mean	69.69387755	57.32653061	57.32653061	44.77959184
Variance	78.68869187	63.10605554	63.10605554	52.25449983
Observations	245	245	245	245
df	482		484	
t Statisitic	16.25659232		18.28488157	
P(T<=t) two-tail	1.07014E-47		3.5924E-57	
t Critical two-tail	1.964897881		1.964877443	

7.0 CONCLUSIONS

In general, the respondents felt really discomfort towards the uneven joint in Jambatan Parit Jamil as the elevation of the uneven joint was higher compared to the joint at Jambatan Parit Haji Ibrahim. This uneven joint creates inconvenience to road users, distracts drivers, reduces steering control, and increase the expenses of maintenance operations. For the safety of the driver, they need to reduce the speed when approaching the uneven joint at the bridge. The situation contributed to the delay of time towards the driver that uses the bridge. The target respondent that can be achieve as 30 respondent taking part in this survey. According to the social survey conducted in the nearby village, 30 (100%) of the respondents feel the impact when maneuvering the bridge. All the results that were obtained were analysed and achieved the objective of this study.

The evaluation of the reduction in traffic speed during maneuvering the uneven joint maneuver was obtained. From the spot speed study, the vehicle will slow down their vehicle at the high elevation of uneven joint. The huge impact of the uneven joint can be seen through the highest reducing speed compared to other elevations of the uneven joint at different bridges. The uneven joint is located at the second point throughout the field study. From the data analysis, the mean speed for all classes of vehicles from second point to third point at Jambatan Parit Jamil show a reduction of 12.48km/h. The reduction in the mean speed from the first point to the second point is 12.93km/h. As a result, the difference reduction of speed is higher from the first point to the second point than from second point to the third point. Those results indicate that the higher reduction of speed is at the second point, which are the uneven joints. The result at Parit Haji Ibrahim shows that the reductions in speed between each point are lower. The difference in speed reduction from the first point to the second point is only 3.15km/h, while the difference in speed reduction between the second point to the third point is 1.55km/h. The lower speed reduction on this bridge was affected by the lower elevation of the uneven joint. In conclusion, the spot speed study and speed analysis achieve the second objective of this research, namely, reducing the reduction in speed by the vehicle during the maneuvering of an uneven joint that can be proven.

Acknowledgements

The authors would like to thank Office of the Research, Innovation and Commercialization Centre (ORICC) UTHM for their financial support under the grant Tier 1 vot H753 for this research.

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