JURNAL TEKNIK SIPIL CENDEKIA
e-ISSN : 2723-3375
doi : **10.51988/jtsc.xxx**
**pp : 708-718**

# Vehicle Speed at Level Crossings with Asphalt and Precast Concrete Pavement

***Tri Ratna Darma Putra[1], Endang Widjajanti[2]**
[1,2] Master of Civil Engineering Study Program, Faculty of Engineering, Institut Sains dan Teknologi Nasional (ISTN), Jakarta, Indonesia
*)triratnadarmaputra@gmail.com

Received : 10 Juli 2026 Revised : 31 Juli 2026 Accepted : 31 Juli 2026

***Abstract***

*Level crossings require pavement surfaces that provide a smooth and stable transition between the roadway and railway tracks. In practice, asphalt and precast concrete panels, commonly referred to as Concrete Level Crossing (CLC), are used as pavement systems at level crossings in Indonesia. Differences in pavement characteristics may influence the speed behavior of vehicles approaching and traversing the crossing. This study evaluates vehicle speed and deceleration characteristics at level crossings with asphalt and CLC pavement on two-lane, two-way rural roads in West Java, Indonesia. Field observations were conducted at JPL 40 on Jalan Raya Cibadak–Sukabumi, which uses CLC pavement, and JPL 118 on Jalan Mohamad Toha, Parung Panjang, which uses asphalt pavement. Vehicle speeds were recorded at three observation points located 100 m and 50 m before the crossing and at the crossing itself. Four vehicle categories were analyzed: motorcycles, passenger cars, medium trucks, and heavy trucks. The results show that vehicles at the CLC crossing generally recorded higher speeds at the crossing point than vehicles at the asphalt crossing. At point C, the average speeds for motorcycles, passenger cars, medium trucks, and heavy trucks were 26.27, 24.07, 28.48, and 23.90 km/h, respectively, at the CLC crossing, compared with 19.59, 20.76, 21.66, and 20.42 km/h at the asphalt crossing. Deceleration characteristics varied according to vehicle type and observation zone. These findings indicate that pavement type is associated with differences in vehicle speed behavior at level crossings and should be considered in the evaluation of crossing pavement performance.*

***Keywords:*** *Level Crossing; Vehicle Speed; Asphalt Pavement; Concrete Level Crossing; Deceleration*



## INTRODUCTION

Level crossings are critical interfaces between road and railway infrastructure because two transportation systems with different operating characteristics intersect at the same elevation. The condition of the road surface at a level crossing is therefore important not only for the durability of the crossing facility but also for the comfort and continuity of road traffic. Inadequate pavement conditions, differences in elevation between the roadway and railway track, and unstable pavement surfaces may affect vehicle movement and contribute to traffic safety problems. A study of level crossings in the Greater Bandung area, for example, identified pavement and elevation conditions as important technical aspects requiring attention in the improvement of level crossing performance [1].

The pavement structure at a level crossing is subjected to repeated loading from road vehicles while also interacting with the railway track structure. Consequently, the pavement at the crossing may require different structural characteristics from those of the adjacent roadway. Previous work on level crossing pavement in Indonesia has noted that conventional flexible asphalt pavement is susceptible to surface deterioration and that a stronger rigid pavement structure can be considered at the crossing area [2]. The use of concrete pavement at level crossings has subsequently received attention as an alternative because it can provide a more stable crossing surface and can be designed specifically to accommodate the interaction between road and railway infrastructure.

One of the concrete pavement systems applied at Indonesian level crossings is the Concrete Level Crossing (CLC), which uses precast concrete panels installed in the crossing area. CLC has been investigated not only from the perspective of structural performance but also in relation to its suitability for traffic loading and service life. A recent study at JPL 317 on the Lamongan–Babat railway line evaluated the reliability and deformation behavior of CLC panels under combined railway and road loading, demonstrating the growing application of CLC as an alternative crossing pavement system in Indonesia [3].

(a) (b)

**Figure 1. Pavement conditions at the study level crossings: (a) asphalt pavement; (b) Concrete Level Crossing (CLC).**

Although pavement condition and structural reliability are important, the response of road users to different crossing surfaces is also relevant. The pavement surface forms part of the immediate driving environment through which vehicles approach and pass the railway tracks. Changes in surface condition, elevation, and perceived crossing smoothness may be reflected in vehicle speed and deceleration behavior. Vehicle speed is particularly important because it represents one of the observable characteristics of traffic behavior when approaching a crossing. A comparison of speed profiles at different pavement conditions can therefore provide additional information for evaluating the operational characteristics of level crossings.

Previous studies in Indonesia have examined level crossing conditions, traffic performance, pavement reliability, and structural behavior. However, these studies have generally focused on crossing safety, traffic congestion, pavement condition, or structural performance rather than directly comparing vehicle speed behavior between asphalt and CLC pavement under field conditions [4], [5]. This leaves a practical gap concerning how vehicles of different classes respond when approaching and traversing level crossings with different pavement surfaces. Such information is relevant because the response may not be uniform across vehicle categories. Motorcycles, passenger cars, medium trucks, and heavy trucks have different dimensions, operating characteristics, and interactions with the pavement surface.

This study addresses that gap by comparing vehicle speed and deceleration characteristics at two rural two-lane, two-way (2/2 UD) level crossings in West Java, Indonesia. The study locations were selected at JPL 40 on Jalan Raya Cibadak–Sukabumi, which uses CLC pavement, and JPL 118 on Jalan Mohamad Toha, Parung Panjang, which uses asphalt pavement. The two locations were selected because their road geometry and traffic volumes were considered sufficiently comparable for a field-based comparative analysis. The original field survey recorded vehicle speeds at three observation points: 100 m before the crossing (point A), 50 m before the crossing (point B), and at the crossing (point C). Four vehicle categories were considered: motorcycles, passenger cars, medium trucks, and heavy trucks. The field survey design and locations are documented in the original study.

The objective of this study is to evaluate and compare vehicle speed and deceleration characteristics at level crossings with asphalt and CLC pavement. The analysis focuses on changes in vehicle speed between the observation points and differences among vehicle categories. By examining both speed and deceleration, the study provides a more detailed description of vehicle behavior at the crossing than a comparison based only on average crossing speed. The findings are expected to contribute to the practical evaluation of pavement treatment at level crossings, particularly for rural road sections where road and railway infrastructure directly interact [6], [7].

## METHOD

### Study Locations

The study was conducted at two level crossings located on two-lane, two-way (2/2 UD) rural roads in West Java, Indonesia. The first site was JPL 40 on Jalan Raya Cibadak–Sukabumi, Sukabumi Regency, where the level crossing uses a Concrete Level Crossing (CLC) pavement system. The second site was JPL 118 on Jalan Mohamad Toha, Parung Panjang, Bogor Regency, where the level crossing uses asphalt pavement. The two locations were selected because they have comparable road and traffic characteristics, allowing a field-based comparison of vehicle speed behavior under different pavement conditions [8].

The geometric characteristics of the two locations are relatively similar. Both road sections have straight horizontal alignment, zero-grade vertical alignment, and no significant side friction. The road widths are 9.3 m at JPL 40 and 9.6 m at JPL 118. The main difference considered in this study is the pavement type at the level crossing, namely CLC at JPL 40 and asphalt at JPL 118.

(a) (b)

**Figure 2. Study locations: (a) JPL 40 with CLC pavement; (b) JPL 118 with asphalt pavement.**

### Traffic and Geometric Characteristics

Traffic volume data were collected at both study locations to characterize the traffic conditions during the observation period. The survey covered the period from 06:00 to 18:00 and classified vehicles into motorcycles, passenger cars, medium trucks, buses, and heavy trucks. The observed hourly traffic volumes at JPL 40 ranged from 1,345 to 2,009 vehicles per hour, while those at JPL 118 ranged from 1,063 to 1,982 vehicles per hour. The traffic composition and hourly variation were considered when evaluating the comparability of the two study sites [4], [9], [10].

For the comparative analysis, particular attention was given to the geometric characteristics of the road sections. Both locations have straight horizontal alignment, zero-grade vertical alignment, and no side friction. The road widths are 9.3 m at JPL 40 and 9.6 m at JPL 118. These similarities provide a basis for comparing vehicle speed characteristics between the two pavement conditions, although the study remains a field comparison between two different sites rather than a controlled experimental test.

**Table 1. Geometric characteristics of the study locations**

| CHARACTERISTIC | JPL 40 | JPL 118 |
|---|---|---|
| Pavement Type | CLC | Asphalt |
| Road Width | 9.3 m | 9.6 m |
| Horizontal Alignment | Straight | Straight |
| Vertical Alignment | Zero grade | Zero grade |
| Side Friction | None | None |

Source: Field survey, 2026.

### Vehicle Speed Measurement

Vehicle speed was measured using a Bushnell Velocity 101911 radar gun, which operates using Doppler radar technology. The instrument was used to record the instantaneous speed of passing vehicles at predefined observation points. The original field survey also used supporting equipment including data recording forms or applications, reflective safety vests, a measuring tape or laser distance meter, and a time recorder.

Three observation points were established along the vehicle approach to each level crossing. Point A was located approximately 100 m before the crossing, point B was located 50 m before the crossing, and point C was located at the level crossing itself. These points represent the approach, deceleration, and crossing zones, respectively. Vehicle speeds were recorded under unobstructed roadway conditions.

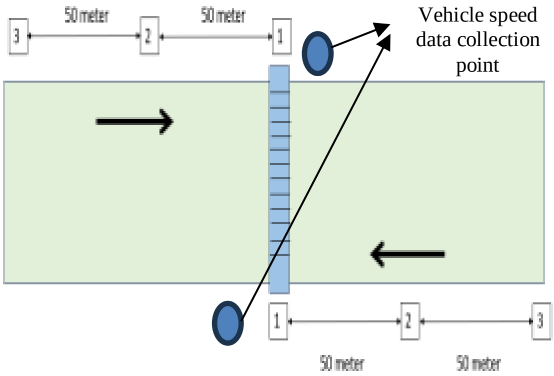


**Figure 3. Vehicle speed observation points at the level crossing.**

### Vehicle Classification and Data Collection

Four vehicle categories were considered in the speed analysis: motorcycles, passenger cars, medium trucks, and heavy trucks. The same vehicle classification was applied at both study locations to maintain consistency in the comparison. For each vehicle category, the observed speeds at points A, B, and C were used to determine the average speed at each observation point.

The field data were subsequently grouped according to location, vehicle category, and observation point. The resulting average speed data were used to describe the vehicle speed profile from the approach zone through the deceleration zone to the crossing zone [11], [12], [13] [14]. The original dataset reports average speeds for all four vehicle categories at the three observation points for both JPL 40 and JPL 118.

### Deceleration Analysis

Vehicle deceleration was calculated to quantify the reduction in speed between consecutive observation points. Before the calculation, vehicle speeds recorded in km/h were converted to m/s. The deceleration magnitude was calculated using the uniformly accelerated motion relationship:

$$a = \frac{v_0^2 - v_t^2}{2s}$$

where:

$a$ = deceleration magnitude (m/s²);

$vo$ = initial speed at the beginning of the observation segment (m/s);

$vt$ = speed at the end of the observation segment (m/s); and

$s$ = travel distance between the two observation points (m).

The calculation was applied to two observation segments: A–B, representing the deceleration zone, and B–C, representing the crossing zone. Each segment has a distance of approximately 50 m. The original study used the same GLBB-based approach after converting speed from km/h to m/s.

### Statistical Analysis

A Kolmogorov–Smirnov normality test was applied to evaluate whether the observed vehicle-speed data followed an approximately normal distribution. The significance level was set at α = 0.05. The null hypothesis was accepted when the calculated maximum deviation ($Dmax$) was lower than the critical value ($Dcritical$), or when the corresponding p-value exceeded the significance level. The original analysis reported that all evaluated speed datasets satisfied the normality criterion, with the calculated $Dmax$ values lower than their respective critical values [15], [16].

The normality assessment was conducted for each vehicle category and observation point at both study locations. The test results were used as a prerequisite for subsequent comparative statistical analysis of vehicle speed between the two pavement conditions.

### Data Analysis Framework

The analysis followed four sequential steps. First, the observed vehicle-speed data were grouped according to pavement type, vehicle category, and observation point. Second, the average vehicle speed at points A, B, and C was calculated to describe the speed profile approaching and traversing each level crossing. Third, the normality of the speed data was evaluated using the Kolmogorov–Smirnov test. Finally, vehicle deceleration was calculated for the A–B and B–C segments and compared between the asphalt and CLC crossings for each vehicle category [15].

The analytical framework was designed to identify whether differences in pavement type were accompanied by differences in vehicle speed and deceleration behavior. Because the comparison involved two field locations rather than a controlled laboratory experiment, the results are interpreted as observed differences between the two crossing conditions, rather than as a direct causal effect of pavement material alone [17].

## RESULTS AND DISCUSSION

### Vehicle Speed Characteristics

The observed vehicle speeds at the three observation points are presented in Table 2. Point A represents the initial approach zone, point B represents the deceleration zone, and point C represents the crossing zone. Overall, vehicle speed decreased progressively from point A to point C at both study locations. This pattern indicates that vehicles generally reduced their speed as they approached and entered the level crossing.

At the asphalt crossing (JPL 118), the average speed decreased from 29.54 to 19.59 km/h for motorcycles, from 33.75 to 20.76 km/h for passenger cars, from 35.20 to 21.66 km/h for medium trucks, and from 32.65 to 20.42 km/h for heavy trucks between points A and C. The corresponding reductions were therefore 9.95, 12.99, 13.54, and 12.23 km/h, respectively.

At the CLC crossing (JPL 40), the average speed also decreased from point A to point C. Motorcycle speed decreased from 36.29 to 26.27 km/h, passenger-car speed from 34.63 to 24.07 km/h, medium-truck speed from 34.52 to 28.48 km/h, and heavy-truck speed from 34.73 to 23.90 km/h. The corresponding reductions were 10.02, 10.56, 6.04, and 10.83 km/h.

The speed profile shows that the largest reduction at the asphalt crossing occurred for medium trucks, while the reduction for medium trucks was substantially smaller at the CLC crossing. This difference is reflected in the speed recorded at point C, where medium trucks at the CLC crossing maintained an average speed of 28.48 km/h compared with 21.66 km/h at the asphalt crossing. The original study similarly identified point C as the location with the lowest observed speed at both crossings.

**Table 2. Average vehicle speed at the three observation points**

| Vehicle Type | Pavement | Point A (Km/H) | Point B (Km/H) | Point C (Km/H) |
|---|---|---|---|---|
| Motorcycle | Asphalt | 29.54 | 25.47 | 19.59 |
| Passenger Car | Asphalt | 33.75 | 27.86 | 20.76 |
| Medium Truck | Asphalt | 35.20 | 29.87 | 21.66 |
| Heavy Truck | Asphalt | 32.65 | 27.81 | 20.42 |
| Motorcycle | Clc | 36.29 | 33.28 | 26.27 |
| Passenger Car | Clc | 34.63 | 30.32 | 24.07 |

| | | | | |
|---|---|---|---|---|
| Medium Truck | Clc | 34.52 | 31.68 | 28.48 |
| Heavy Truck | Clc | 34.73 | 28.63 | 23.90 |

Source: Field survey, 2026.

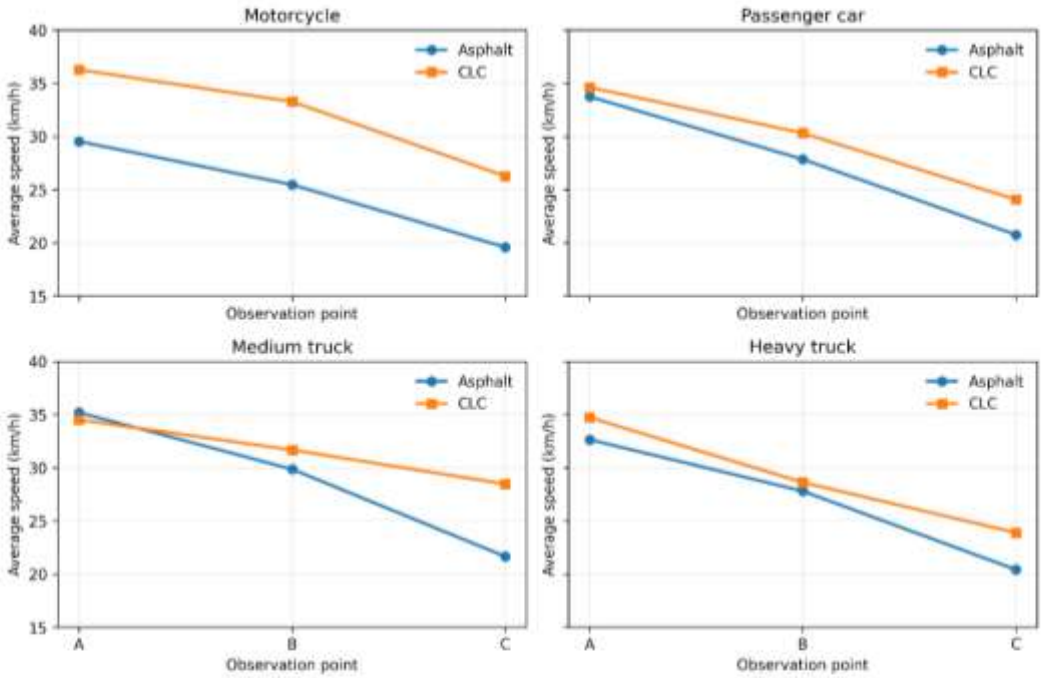


**Figure 4. Average vehicle speed profiles at the asphalt and CLC level crossings.**

**Comparison of Speed at the Crossing Point**

A direct comparison of vehicle speeds at the crossing point provides a clearer indication of the difference between the two pavement conditions. As shown in Table 3, the average speed at point C was higher at the CLC crossing for all four vehicle categories. The difference was 6.68 km/h for motorcycles, 3.31 km/h for passenger cars, 6.82 km/h for medium trucks, and 3.48 km/h for heavy trucks**.**

The largest absolute difference occurred for medium trucks, with a difference of 6.82 km/h, followed closely by motorcycles with a difference of 6.68 km/h. In relative terms, the CLC crossing recorded approximately 34.10% higher motorcycle speed and 31.49% higher medium-truck speed than the asphalt crossing. Passenger cars and heavy trucks showed smaller relative differences of approximately 15.94% and 17.04%, respectively.

These results indicate that the difference in crossing speed was not uniform across vehicle categories. The larger differences observed for motorcycles and medium trucks suggest that vehicle response at the crossing may vary according to vehicle type. Nevertheless, because the comparison was conducted at two different field locations, the observed differences should be interpreted as differences between the two crossing conditions, rather than as evidence that pavement material alone directly caused the change in speed.

**Table 3. Average speed difference at the crossing point**

| Vehicle Type | Asphalt, C (Km/H) | Clc, C (Km/H) | Difference (Km/H) | Clc Relative To Asphalt |
|---|---|---|---|---|
| Motorcycle | 19.59 | 26.27 | +6.68 | +34.10% |
| Passenger Car | 20.76 | 24.07 | +3.31 | +15.94% |

| | | | | |
|---|---|---|---|---|
| Medium Truck | 21.66 | 28.48 | +6.82 | +31.49% |
| Heavy Truck | 20.42 | 23.90 | +3.48 | +17.04% |

Source: Calculated from field survey data.

**Speed Reduction Between Observation Points**

The changes in speed between consecutive observation points provide additional information about the location of the main speed reduction. At the asphalt crossing, the speed reduction during the B–C segment was greater than during the A–B segment for all vehicle categories. The B–C reduction reached 8.21 km/h for medium trucks and 7.39 km/h for heavy trucks. This indicates that the largest reduction in speed at the asphalt crossing occurred closer to and within the crossing zone.

A similar pattern was observed for motorcycles and passenger cars at the CLC crossing, where the reduction in the B–C segment was greater than that in the A–B segment. However, medium trucks showed only a 3.20 km/h reduction in the B–C segment, considerably lower than the 8.21 km/h observed for medium trucks at the asphalt crossing. Heavy trucks showed a different pattern, with a larger speed reduction during A–B than during B–C. These variations demonstrate that vehicle speed response is dependent not only on the crossing condition but also on vehicle category and the specific approach segment.

**Asphalt — JPL 118**

| Vehicle | A–B Reduction | B–C Reduction |
|---|---|---|
| Motorcycle | 4.07 Km/H | 5.88 Km/H |
| Passenger Car | 5.89 Km/H | 7.10 Km/H |
| Medium Truck | 5.33 Km/H | 8.21 Km/H |
| Heavy Truck | 4.84 Km/H | 7.39 Km/H |

**CLC — JPL 40**

| Vehicle | A–B Reduction | B–C Reduction |
|---|---|---|
| Motorcycle | 3.01 Km/H | 7.01 Km/H |
| Passenger Car | 4.31 Km/H | 6.25 Km/H |
| Medium Truck | 2.84 Km/H | 3.20 Km/H |
| Heavy Truck | 6.10 Km/H | 4.73 Km/H |

**Normality Test**

The Kolmogorov–Smirnov test was used to assess the distribution of the observed vehicle-speed data before conducting the comparative analysis. The results are presented in Table 4. The values for all vehicle categories and observation points were lower than their corresponding critical values. For example, at JPL 118, the values for motorcycles at points A, B, and C were 0.105, 0.086, and 0.115, respectively, compared with a critical value of 0.134. Similar relationships were observed for the other vehicle categories and at the CLC location.

The normality results therefore indicate that the observed speed datasets satisfied the normality criterion used in the original analysis. This provides a statistical basis for proceeding with comparative analysis of the speed characteristics between the two crossing conditions.

**Table 4. Kolmogorov–Smirnov normality test results**

| Pavement | Vehicle Type | Dmax At A | Dmax At B | Dmax At C | Dcritical |
|---|---|---|---|---|---|
| Asphalt | Motorcycle | 0.105 | 0.086 | 0.115 | 0.134 |
| Asphalt | Passenger Car | 0.041 | 0.110 | 0.123 | 0.144 |

| | | | | | |
|---|---|---|---|---|---|
| Asphalt | Medium Truck | 0.071 | 0.105 | 0.139 | 0.155 |
| Asphalt | Heavy Truck | 0.202 | 0.204 | 0.121 | 0.259 |
| Clc | Motorcycle | 0.125 | 0.110 | 0.120 | 0.129 |
| Clc | Passenger Car | 0.133 | 0.059 | 0.102 | 0.144 |
| Clc | Medium Truck | 0.084 | 0.078 | 0.076 | 0.171 |
| Clc | Heavy Truck | 0.080 | 0.095 | 0.092 | 0.210 |

Source: Statistical analysis, 2026.

## Deceleration Characteristics

The calculated deceleration values are presented in Table 5. The results show that the magnitude of deceleration varied among vehicle categories and between the two observation segments. At the asphalt crossing, the highest deceleration in the A–B segment was recorded for passenger cars at 0.29 m/s², followed by medium trucks at 0.27 m/s². In the B–C segment, medium trucks recorded the highest deceleration at 0.33 m/s², while motorcycles recorded the lowest value at 0.21 m/s².

At the CLC crossing, the A–B deceleration ranged from 0.15 to 0.30 m/s². Heavy trucks showed the highest value at 0.30 m/s², whereas medium trucks showed the lowest value at 0.15 m/s². In the B–C segment, motorcycles recorded the highest deceleration at 0.33 m/s², while medium trucks remained at 0.15 m/s².

The results demonstrate that the deceleration response was not consistent across vehicle types. For example, motorcycle deceleration in the B–C segment was higher at the CLC crossing (0.33 m/s²) than at the asphalt crossing (0.21 m/s²), whereas heavy-truck deceleration was lower at the CLC crossing (0.19 m/s²) than at the asphalt crossing (0.27 m/s²). Medium trucks showed the largest contrast, with deceleration of 0.33 m/s² at the asphalt crossing and only 0.15 m/s² at the CLC crossing during B–C.

These findings suggest that differences in vehicle speed behavior at the two crossings cannot be described using pavement type alone. Vehicle category and the position of the vehicle relative to the crossing also appear to be important factors in determining the observed deceleration response.

**Table 5. Average vehicle deceleration between Observation Zones**

| Pavement | Vehicle Type | A–B (M/S²) | B–C (M/S²) |
|---|---|---|---|
| Asphalt | Motorcycle | 0.17 | 0.21 |
| Asphalt | Passenger Car | 0.29 | 0.28 |
| Asphalt | Medium Truck | 0.27 | 0.33 |
| Asphalt | Heavy Truck | 0.23 | 0.27 |
| Clc | Motorcycle | 0.17 | 0.33 |
| Clc | Passenger Car | 0.22 | 0.27 |
| Clc | Medium Truck | 0.15 | 0.15 |
| Clc | Heavy Truck | 0.30 | 0.19 |

Source: Statistical Analysis, 2026.

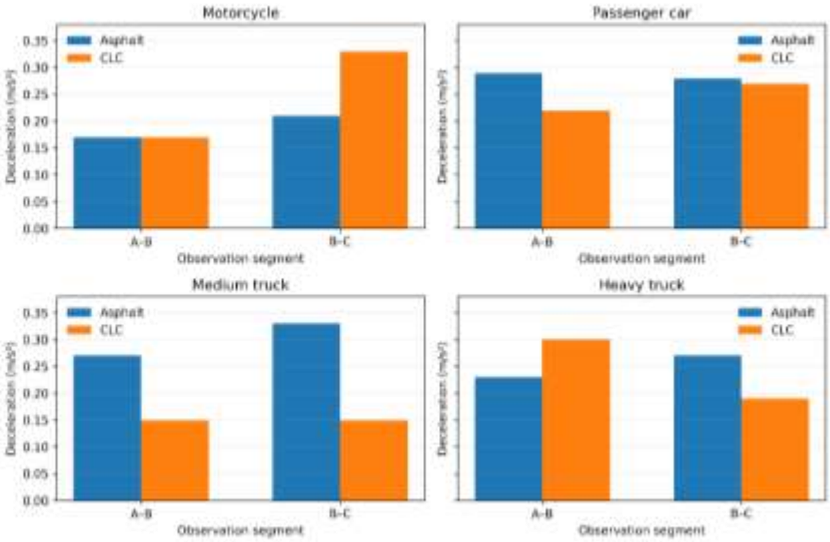


**Figure 5. Vehicle deceleration at the asphalt and CLC level crossings.**

**Interpretation of Speed and Deceleration Behaviour**

The combined speed and deceleration results provide a more detailed picture of vehicle behaviour at the two level crossings. The most consistent finding is that vehicle speed decreased from point A to point C at both locations, confirming that drivers generally reduced speed when approaching the railway crossing. However, the magnitude and distribution of the speed reduction differed between vehicle categories and pavement conditions.

At the crossing point, all four vehicle categories recorded higher average speeds at the CLC crossing than at the asphalt crossing. The difference was particularly pronounced for motorcycles and medium trucks. This observation is consistent with the overall conclusion of the original study, which reported higher crossing speeds at the CLC location than at the asphalt location.

The deceleration results, however, do not show the same uniform pattern. Some vehicle categories exhibited greater deceleration at the CLC crossing, whereas others exhibited greater deceleration at the asphalt crossing. Therefore, higher crossing speed at the CLC location should not automatically be interpreted as a lower or higher level of safety. Instead, the result indicates a different vehicle speed response under the observed crossing conditions.

From an engineering perspective, the findings suggest that pavement condition at a level crossing should be evaluated together with vehicle operating behavior. A smoother or more stable crossing surface may allow vehicles to maintain a relatively higher speed through the crossing, while the surrounding road geometry, approach conditions, traffic composition, and driver behavior may also contribute to the observed speed profile. Because this study compares two existing field locations, these factors cannot be completely isolated from the pavement type. The findings should therefore be interpreted as an empirical comparison of observed crossing conditions rather than as a controlled causal experiment.

## CONCLUSION

This study compared vehicle speed and deceleration characteristics at two level crossings with different pavement conditions, namely asphalt and Concrete Level Crossing (CLC), on two-lane, two-way rural roads in West Java, Indonesia. Based on the field observations and analysis, the following conclusions can be drawn.

1. Vehicle speed decreased progressively from the approach zone to the crossing zone at both study locations. At the asphalt crossing, the average speed decreased from point A to point C for motorcycles, passenger cars, medium trucks, and heavy

trucks. A similar reduction was observed at the CLC crossing, indicating that vehicles generally reduced their speed when approaching and traversing the level crossing.

2. The CLC crossing recorded higher average speeds at the crossing point for all four vehicle categories. At point C, the average speeds at the CLC crossing were 26.27 km/h for motorcycles, 24.07 km/h for passenger cars, 28.48 km/h for medium trucks, and 23.90 km/h for heavy trucks, compared with 19.59, 20.76, 21.66, and 20.42 km/h, respectively, at the asphalt crossing. The largest absolute differences were observed for medium trucks (6.82 km/h) and motorcycles (6.68 km/h).
3. Vehicle deceleration varied according to vehicle category and observation segment. At the asphalt crossing, the highest deceleration in the A–B segment was observed for passenger cars (0.29 $m/s^2$), while the highest B–C deceleration occurred for medium trucks (0.33 $m/s^2$). At the CLC crossing, heavy trucks recorded the highest A–B deceleration (0.30 $m/s^2$), whereas motorcycles recorded the highest B–C deceleration (0.33 $m/s^2$). These variations indicate that the deceleration response cannot be characterized by pavement type alone.
4. The comparison indicates a different vehicle speed response between the two observed crossing conditions. Although the CLC crossing showed higher speeds at the crossing point, this result should not be interpreted directly as evidence of either improved or reduced safety. The study compares two existing field locations, so pavement type cannot be completely separated from other site-specific factors such as road geometry, traffic composition, and driver behavior.

Overall, the findings demonstrate that pavement condition is an important aspect to consider when evaluating vehicle operating behavior at level crossings, but its observed relationship with vehicle speed and deceleration should be assessed together with vehicle characteristics and local crossing conditions.

## ACKNOWLEDGEMENT

The authors would like to thank all parties who supported the field survey and data collection activities conducted in this study. The authors also appreciate the assistance provided during the vehicle speed observations at the study locations.

## BIBLIOGRAPHY

[1] Y. A. Tanne, H. Safira, O. T. R. Zai, R. Meilani, and S. A. Kurnia, “Evaluation of level crossings (Case study: Greater Bandung),” *Jurnal Perkeretaapian Indonesia*, vol. 8, no. 1, 2024, doi: 10.37367/jpi.v8i1.313.

[2] M. A. Kurniawan, S. W. Astuti, P. Dewi, H. W. Puruhita, and W. Riyanta, “Perencanaan perkerasan jalan raya pada perlintasan sebidang di JPL 136 Kota Madiun,” *Jurnal Teknik Industri Terintegrasi (JUTIN)*, vol. 7, no. 4, pp. 2475–2484, 2024, doi: 10.31004/jutin.v7i4.37006.

[3] S. R. Andriyani, M. Nurhadi, and P. Dewi, “Analisis keandalan penggunaan Concrete Level Crossing untuk lalu lintas pada perlintasan sebidang JPL 317 lintas Lamongan–Babat,” *Jurnal Transportasi*, vol. 24, no. 2, pp. 169–178, 2024, doi: 10.26593/jtrans.v24i2.8986.169-178.

[4] O. K. Ng and F. F. Saccomanno, “Speed reduction profiles affecting vehicle interactions at level crossings with no trains,” *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2149, no. 1, pp. 108–114, 2010, doi: 10.3141/2149-13.

[5] E. Tenkink and R. van der Horst, “Car driver behavior at flashing light railroad grade crossings,” *Accident Analysis & Prevention*, vol. 22, no. 3, pp. 229–239, 1990, doi: 10.1016/0001-4575(90)90015-D.

[6] L. Åberg, “Driver behavior at flashing-light, rail-highway crossings,” *Accident*

*Analysis & Prevention*, vol. 20, no. 1, pp. 59–65, 1988, doi: 10.1016/0001-4575(88)90015-2.

[7] Z. Zhang, M. Dhanasekar, L. Ling, and D. P. Thambiratnam, "Effectiveness of a raised road: rail crossing for the safety of road vehicle occupants," *Engineering Failure Analysis*, vol. 97, pp. 258–273, 2019, doi: 10.1016/j.engfailanal.2019.01.046.

[8] S. M. S. Shah, S. M. A. H. M. R. M. and colleagues, "Safety and associated parameters influencing performance of rail road grade crossings: A critical review of state of the art," *Journal of Safety Research*, vol. 79, pp. 257–272, 2021, doi: 10.1016/j.jsr.2021.09.007.

[9] C. M. Rudin-Brown, M. French-St. George, and J. J. Stuart, "Human factors issues of accidents at passively controlled rural level crossings," *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2458, no. 1, 2014, doi: 10.3141/2458-12.

[10] G. S. Larue, C. Wullems, M. Sheldrake, and A. Rakotonirainy, "Validation of a driving simulator study on driver behavior at passive rail level crossings," *Human Factors*, vol. 60, no. 6, 2018, doi: 10.1177/0018720818783507.

[11] H. E. Clark, J. A. Perrone, and R. B. Isler, "An illusory size–speed bias and railway crossing collisions," *Accident Analysis & Prevention*, vol. 55, pp. 226–231, 2013, doi: 10.1016/j.aap.2013.02.037.

[12] E. R. Russell, H. D. Shah, and M. J. Rys, "Study of drivers' behavior at passive railroad-highway grade crossings," *Journal of the Transportation Research Forum*, vol. 48, no. 2, 2012, doi: 10.5399/osu/jtrf.48.2.2266.

[13] T. M. Prasetyo, S. Putra, and S. A. M. P. Ofrial, "Perlambatan waktu perjalanan akibat perlintasan sebidang kereta api (Studi kasus: Jalan Hos Cokroaminoto, Kebon Jahe Tanjung Karang)," *Jurnal Rekayasa Sipil dan Desain*, vol. 11, no. 1, 2023, doi: 10.23960/jrsdd.v11i1.3123.

[14] F. Muharam *et al*., "Development of a microsimulation model for railway level crossings on urban roads using PTV VISSIM," *Media Komunikasi Teknik Sipil*, vol. 30, no. 2, pp. 186–195, 2024, doi: 10.14710/mkts.v30i2.63892.

[15] Directorate General of Railways, *Perkeretaapian dalam Angka*. Jakarta, Indonesia: Ministry of Transportation, 2023.

[16] Ministry of Transportation of the Republic of Indonesia, *Regulation of the Minister of Transportation No. PM 60 of 2012 on Technical Requirements for Railway Tracks*, Jakarta, Indonesia, 2012.

[17] Directorate General of Railways, *Perencanaan Perlintasan Jalan dengan Jalur Kereta Api*. Jakarta, Indonesia: Ministry of Transportation, 2004.