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Micro Surfacing Asphalt Pavement as a Mitigation Measure at Accident's Prone Area along East Coast Expressway Phase 2 (ECE 2)

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Abstract – *The condition of pavement surface is an essential factor to be considered in mitigation of accidents in highways, as it is in direct contact with users' vehicles, especially in terms of quality of driving, skid resistance and friction. Lack of surface pavement maintenance may lead to accidents, and if taken for granted, it may witness high accident fatalities in the expressways. If the cause of the accidents happening on the roads is due to engineering factors, then adequate mitigation measures should be undertaken to avoid further tragedies from happening. One way of mitigating the accidents on highways is by conducting periodic maintenance of the roads and related highway infrastructure. Micro-surfacing is one of the potential measures, developed from a slurry seal technique. It is the process of applying a mixture of polymer modified bitumen emulsion with 8.0 mm chipping, quarry dust, cement, additives and water on an existing asphalt pavement surface. The current study was carried out to evaluate the performance of micro-surfacing as a mitigation measure, applied on the accident-prone pavement areas along the East Coast Expressway Phase 2 (ECE2). The Portable Pendulum Tester was used to evaluate the skid resistance performance while the texture depth of micro-surfacing was measured using the Sand Patch Test. The results showed tremendous improvement in the skid resistance and texture depth after the application of micro-surfacing. The number of accidents also reduced after the application of micro-surfacing asphalt pavement as a mitigation measure at the identified accident-prone areas along ECE2. Thus, the study confirmed that micro-surfacing asphalt pavement was effective in mitigating the accidents in accident-prone areas along ECE2.*

Keywords: Micro-surfacing, accident-prone area, asphalt pavement, slurry seal, East Coast Expressway (ECE)

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1.0 INTRODUCTION

The East Coast Expressway Phase 2 (ECE2) is an extension of East Coast Expressway Phase 1 (ECE1), which connects Western and Eastern parts of peninsular Malaysia, running from Kuala Lumpur to Terengganu State. The development of roads and highway infrastructure of ECE2 between Jabor, Kemaman to Kampung Gemuroh, Kuala Terengganu comprises a total length of about 184km, which is being carried out in stages. The construction commenced in May 2006 and was partially completed in 2012, and the overall completion was in 2015. ECE2 is a Dual Lane Two Carriageway highway with a design speed of 120 km/h (Speed Limit 110 km/h) and has been designed as a toll highway (Closed Toll System), which includes the construction of a Toll Plaza, Rest & Services Area (RSA), Laybys, Telecommunication System, Traffic Control Centre, administration building and a maintenance depot. The construction of ECE2 was divided into two sections. About 30% of the total length of ECE2 from Bukit Besi to Telemung (64km), and Payung Spur Road (16km) is under supervision by the Malaysian Highway Authority (MHA), for which the turnkey Contractor was MTD CAPITAL Bhd. The remaining 70% was supervised by the Malaysia Public Works Department (PWD – JKR) by conventional tender. The overall cost of the ECE2 Project was about 4.25 billion. The expressway has been constructed through a swampy and flood-prone area wherein an intensive soil treatment process was performed to ensure smooth driving along the section. The soil treatment methods that were employed were pile embankment, Pre – Fabricated Vertical Drain (PVD), Dynamic Compaction and stone column to ensure that it meets the specification of the total settlement, i.e., within 50mm in 20 years (Malaysia Highway Authority, 2017).

Upon the completion of the whole alignment of ECE2 on 31st January 2015, instead of Malaysia Highway Authority (MHA) package, the entire JKR package was handed over to MHA who had managed the operation and maintenance aspects before handing over to the concessionaire for privatization. From there, MHA played their roles in managing the expressway in terms of operations and maintenance aspects, according to the specifications and standards. The effective date of privatization of the ECE2 was on July 2016, wherein the whole alignment of the expressway was handed over to LPT2 Sdn. Bhd., a private company with liabilities involving maintaining, operating, and managing the expressway according to the requirements and standards fixed by MHA. Since the effective date of the privatization, the LPT2 Sdn Bhd availed the privilege to collect tolls from the users as officially stated in the Concession Agreement (Malaysia Highway Authority, 2017).

Periodic maintenance works for all the highway assets such as bridges, pavement, drainage, slope, turfing, road furniture and all the related infrastructure was essential and required specialized expertise and tools to ensure that all of the assets are in good condition and to ensure the safety of the users (Lu & Meng, 2018). The performance of the pavement is one of the major asset cum indicators that demonstrates the reliability and quality of the expressway and the commitment of the concessionaire in maintaining the expressway. Poor quality of the pavements will affect the service level to the road users. A proper maintenance regime through routine maintenance and restoration work is detrimental to extend the lifetime of the pavement. The pavement surface condition should also be seriously taken into consideration as it is in direct contact with the user vehicles, especially in terms of quality of driving (driving comfort), skid resistance and friction. If accidents occur as a result of engineering factors or issues, then appropriate and immediate mitigation measures must be undertaken to avoid such scenarios.

According to that accident statistics report, 70% of the accidents (1,493 accidents) occurred due to human factors, the environment and surrounding factors caused 16% (368 accidents), and 14% (303 accidents) corresponded to vehicle factors. From the statistics, there were 45 fatal accidents, 117 injuries involving severe injuries and 377 accidents involving minor injuries, and the rest did not involve any injuries (Malaysia Highway Authority, 2017). The Malaysia Highway Authority (MHA) and the Lebuhraya Pantai Timur 2 Sdn. Bhd. (LPT2SB), as a highway concessionaire, have taken several mitigation measures along the highway to address these issues. Several measures were undertaken, such as installing micro surfacing asphalt pavement to increase the skid resistance, install of warning signs (chevron), yellow/red transverse bar, and light reflection stickers along the guardrails and parapet bridges (Zhao et al., 2015; Martinelli et al., 2018). Also, the Alert Bar Marking for prompting the vehicles to slow down their speeds and the repair drainage system to tackle water crossing were implemented.

Although most of the accidents happened due to human negligence and errors, MHA and the concessionaire had to take some appropriate action to investigate the possibility of other issues contributing to the factors mentioned above. Based on the statistics and the investigation at the site, a certain number of accidents happened due to vehicle skidding, which was high during rainy days (Malaysia Highway Authority, 2017). About 27 accidents were due to vehicle skidding, especially during the rainy season. One of the mitigation measures, i.e. using Micro Surfacing Asphalt Pavement, was proposed to avoid skidding of vehicles. Micro-surfacing is defined as a modified version of slurry seal and was introduced in Canada in the early 1990s. Micro-surfacing was used to restore the pavement surface characteristics and to preserve the quality of the pavement surface. This surfacing mixture can be designed to correct rutting, improve skid resistance, seal surface cracks, and protect pavement surfacing against hardening and improve the surface texture. For that reason, Malaysia has been using micro-surfacing in most of the roadways since 2008. No other form of asphalt micro-surfacing treatment was employed until then. The asphalt pavement was layered along the carriageway at the accident-prone areas. In Malaysia, micro surfacing has been extensively used to improve skid resistance and to prolong the life span of the pavement (Malaysia Public Works Department, 2008).

Therefore, the study lays three primary objectives to understand the cause and effect of the issues discussed earlier. They are, namely (1) to identify the factors causing accidents at the identified locations in accident-prone areas; (2) to determine the type of accident that results from vehicle skidding at accident-prone areas along ECE2 and; (3) to evaluate the performance of micro-surfacing asphalt pavement layer using the skid resistance test, surface texture depth and the number of accidents after the mitigation measures were taken.

2.0 METHODOLOGY

The East Coast Expressway Phase 2 (ECE2) has been chosen in the study because it was a new alignment of highway constructed on the East Coast of Peninsular Malaysia. Also, micro surfacing asphalt pavement is one of the mitigation measures that has been implemented in ECE2 to reduce the rates of accident occurrences at the identified accident-prone areas. The ECE2 is a dual lane two carriageway and is designed as a closed toll system with a design speed of 120 km/h. The ECE2 (route number E8) starts at KM250.60 at Jabor, Kemaman, Terengganu and ends at KM428.00 at Interchange Kuala Terengganu, Kg. Gemuroh, Kuala Terengganu, Terengganu wherein the whole length of expressway is located within the state of

Terengganu, Malaysia. The ECE2 is relatively well developed compared to other highways, as it boasts of technical features that are more advanced compared to any other highway in Malaysia. The lane width of the North-South Expressway (NSE) is 3.55m, which is less than ECE2 and has a median along the highway.

2.1 Data of Accidents along East Coast Expressway Phase 2 (ECE2)

The safety of the ECE2 users is the top priority to the government, wherein the whole alignment of the expressway is continuously monitored by the highway patrol car. All the accidents happening along the highway will be attended and managed by the highway's patrol car in collaboration with the Polis Diraja Malaysia (PDRM). The data of every accident will be collected, and the report will be submitted to the Malaysian Highway Authority (MHA). According to the MHA (2017), the Average Daily Traffic (ADT) along the ECE2 in the year 2015 was about 13,000 vehicles per day and the traffic increased to 17,000 per day in the year 2017. The process of collecting accident data is usually started once an accident happens along the highway. The patrolman will do some preliminary investigation at the location of accidents and sometimes together with the policeman on site. From the observation of the site, type of accident, weather, condition of the highway/road, surrounding environment, day and night, and basic inspection of the vehicles involved, details are recorded in the report (Malaysia Highway Authority, 2017).

Upon the opening of ECE2 to the users, it witnessed an increment in the accident rate along the highway raising several concerns and controversial issues to the government and the highway authority. According to the relevant reports from February 2015 until February 2017 (Malaysia Highway Authority, 2017), 70 % of the accidents (1493 accidents) were caused by human factors, the environment caused 16% (368 accidents), and surrounding factor and 14% (303 accidents) corresponded to vehicle factors. From the statistics, there were 45 fatal accidents, 117 injuries involving severe injuries and 377 accidents involving minor injuries, and the rest did not involve any injuries. Figure 1 shows the trend of accidents along ECE2 from February 2015 to February 2017, and Figure 2 shows the percentage of different factors causing accidents in the ECE2 from February 2015 until February 2017.

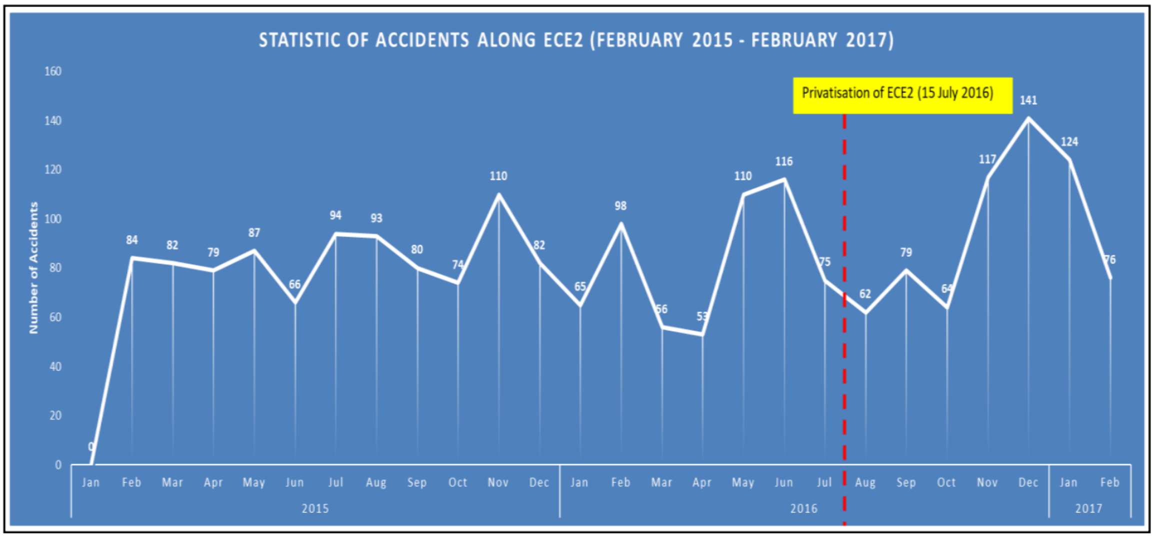

Figure 1: Statistics on accidents along ECE2 between February 2015 and February 2017 (Source: Malaysia Highways Authority, 2017)

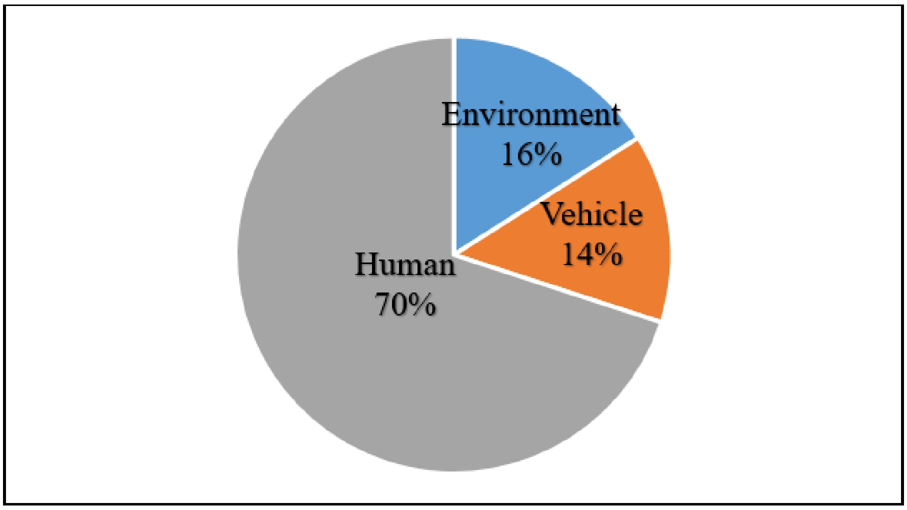

Figure 2: Factors causing accidents along the East Coast Expressway Phase 2 (ECE2) from February 2015 until February 2017
(Source: Malaysia Highway Authority, 2017)

2.2 Accident's Prone Area along East Coast Expressway Phase 2 (ECE2)

Several mitigation measures were implemented to solve the problem and cause of accidents at the identified prone areas. It was essential to determine whether the accidents were either caused by highway engineering itself or other factors related to the driver. In this paper, the focus will mainly be on the stretch between KM312.30 – KM314.10 (South bound) where micro-surfacing was employed as a mitigation measure to reduce the number of accidents (Figure 3).

2.3 Wet-weather Crash and Pavement Surface Condition

Road crashes have been recognized as one of the common accidents, which is a result of one or more factors from three main categories: driver-related, vehicle-related and road condition-related (Noyce et al., 2005). The Road and Highway Authorities have full control of the standard and condition of their roads through effective design, construction and maintenance police. Pavement surface properties, such as skid resistance and texture depth, greatly influence the effectiveness of the physical contact of the pavement aggregates with the vehicle's tires.

The wet-weather crashes increase as pavement friction decreases. A study on the M4 highway, England showed pavement resurfacing (increased pavement friction) resulted in a 28% reduction of dry pavement crashes and a 63% reduction of wet pavement crashes. A study by Xiao et al. (2000) from the Pennsylvania Transportation Institute (PTI) using fuzzy logic models showed that the safety condition could be improved by nearly 60% if the skid number increased from 33.4 to 48.0.

Figure 3: Locations of laying micro surfacing asphalt pavement at the accident's prone area (Source: Malaysia Highway Authority, 2017)

2.4 Pavement Friction

Pavement friction is a force that resists relative motion between vehicle tire and pavement surface. This force is generated as the tire rolls or slides over the pavement surface. It plays a vital role in keeping a vehicle stable on the road by allowing the driver to be in control of his vehicle in a safe manner. In geometric road design, pavement friction is an important parameter as it is used to determine the minimum stopping sight distance, minimum horizontal curve radius and maximum super-elevation. Pavement friction is offered by skid resistance properties of the pavement surface aggregates. These properties depend on the micro and macrotexture of the aggregate surface (Corley-Lay, 1998). Microtexture refers to the small-scale texture of the pavement aggregate component, which controls contact between the rubber tire and the pavement surface by providing frictional potential during braking and acceleration. Micro-texture values can be measured using a method like the British pendulum test. In comparison, macrotexture refers to the large-scale texture of the pavement as a whole due to the aggregate sizes and particle arrangement which controls the escape of water from under the tire. Poor draining of water during rainfall may create thin laminar of water, which may reduce the physical contact in the tire-pavement interaction and hence the loss of skid resistance (Malaysia Public Works Department, 2018). The pavement texture depth is typically measured using the sand patch method and will vary depending on the voids of the surfacing.

2.5 Pavement Surface Drainage

Wet weather conditions are a huge concern in determining the skid resistance, as it is common that drainage of rainwater from the pavement surface would play an important role (Erwin, 2007). Proper drainage can mitigate hydroplaning and the development of Water Film Thickness (WFT) on the pavement. The water film that contributes to hydroplaning is the mean texture depth (MTD) and the thickness of the water film above the top of the surface (Anderson et al., 1998).

The development of Water Film Thickness (WFT) depends on the macrotexture of the pavement surface, and the water below the MTD is trapped in the surface and does not contribute to the drainage of the pavement. One of the methods of controlling WFT is to maximize the texture of the pavement surface. Since WFT is the total thickness of the film of water on the pavement subtracting the water trapped in the macrotexture of the pavement surface, WFT can be reduced in direct proportion with an increase in macrotexture (Erwin, 2007).

2.6 Site Observations

All the locations of accident-prone areas have been closely monitored and observed by the highway concessionaire and the MHA before proposing any mitigation measure to tackle the cause of the accident. In this case, the condition of the chosen accident-prone area is investigated by the concessionaire, LPT2 Sdn. Bhd. as directed by the MHA. From the observation, there were no rutting or any notable defects found in the focused area. In most of the places, the surface pavement was polished, and be clearly observed in the photo taken at the locations. Figures 4 to 7 show the images of site observation and inspection carried out at KM312.30 to KM314.10 (South bound) by the consultant Opus International (M) Sdn. Bhd. and LPT2SB in July 2017. The stretch is about 1,800m.

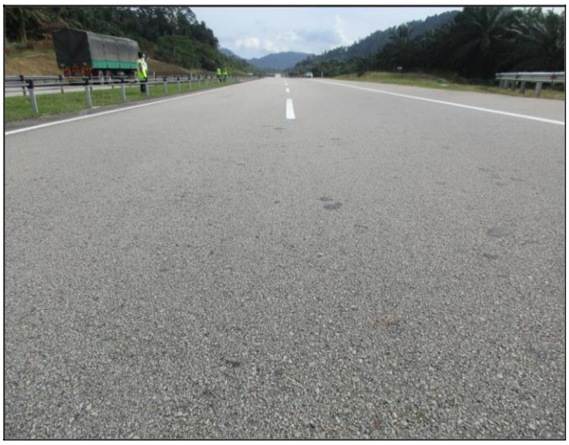

Figure 4: Ageing and polished surface of the existing pavement

Figure 5: No Rutting or pavement undulations observed along the stretch

Figure 6: Ageing and polished surface of the existing pavement

Figure 7: Proper Drainage System in the median to cater surface water runoff at KM313.7 – KM313.9 (South bound)

2.7 Skid Resistance Test - British Pendulum Tester (BPT)

In general, the friction resistance of driest pavements is relatively high than wet pavements; however, the latter always poses problems for vehicles. The number of accidents on wet pavements is twice as high as on dry pavements. It would be incorrect to say that a pavement type has a specific friction factor because friction involves two bodies, the tires and the pavement, which is extremely variable due to pavement wetness, vehicle speed, temperature, tire wear, tire type, etc. (Jayawickrama et al., 1996). Typical friction tests specify standard tires and environmental conditions to overcome the phenomenon of skid.

The skid resistance value is determined for an interval of every 200 metres along the identified stretch on the pavement surface for each lane. Each point shall be tested at least five times using the pendulum tester at every lane (slow lane and fast lane). The skid resistance values and the pavement temperature were recorded in the data collection form. Finally, the mean value of the skid resistance is taken into account considering the variations in the pavement temperature. According to the Malaysia Public Works Department, based on the standard specification for road works: Flexible Pavement, clause 4.13.8.5 (2008) states that the skid resistance value of the completed material on the carriageway shall have a minimum average value of 46 (corrected to 35°C) as measured by the SRT pendulum device. In this study, the data was only collected for a duration of 12 months due to miscellaneous circumstances.

2.8 Texture Depth Measurement – Sand Patch Test

Although pavement skid resistance is related to surface macrotexture, some methods are used to measure the pavement's macrotexture first, and then correlate it with skid resistance which is measured by a more traditional method. The simplest method of surface texture measurement is the sand patch test (ASTM-E 965). The tests are carried out on a dry pavement surface by pouring a known quantity of sand onto the surface and spreading it in a circular pattern with a straightedge. As the sand is spread, it fills the low spots in the pavement surface. When the sand cannot be spread any further, the diameter of the resulting circle is measured. This diameter can then be correlated to an average texture depth, which can be correlated with the skid resistance. A texture depth of about 1.5 mm (0.06 inches) is typically required for heavily trafficked areas (ASTM E 965).

The test was conducted by the supplier ACP-DMT Sdn. Bhd. and verified by the consultant Opus International (M) Sdn. Bhd. on behalf of the highway concessionaire LPT2SB. The test was conducted based on BS598 Part 105 (1990). The texture depth was recorded for every 200m interval for each lane (slow lane and fast lane) along the identified stretch on the pavement surface and the tested point were close to the locations where the skid resistance values were measured. For each sample, the average diameter of the circular sand patch is calculated by measuring the diameter at four different angles.

3.0 RESULTS AND DISCUSSION

The study was conducted to determine the performance of micro surfacing asphalt pavement as a mitigation measure at the accident-prone areas along the East Coast Expressway Phase 2 (ECE2) in the Malaysian state of Terengganu State. The analysis compared the data of accidents and highway pavement surface performance in terms of friction (skid resistance and texture depth) before and after the mitigation measure was implemented in the site. The raw data of accidents and test results were obtained from the highway concessionaire of ECE2, i.e., Lebuhraya Pantai Timur Fasa 2 Sdn. Bhd. (LPT2SB) through the Malaysia Highway Authority (MHA). The analyses focused on accident-prone areas wherein micro surfacing asphalt pavement was implemented as a mitigation measure to reduce the corresponding rate of accidents.

3.1 Factors of Accidents at the Accident's Prone Area

The data were obtained from the statistical report on accidents along the East Coast Expressway Phase 2 (ECE2) from February 2015 until February 2017. The highway concessionaire LPT2SB recorded all the accidents that happened along the ECE2, and the reports were periodically submitted to MHA every month. This was part of the many obligations that the highway concessionaire should follow and fulfil as a requirement indicated in the concession agreement. The analysis was based on the data of accidents on the identified accident-prone areas along ECE2 starting from February 2015 until February 2017, which was actually before the implementation of any mitigation measures in the site. The date of completion of laying micro surfacing asphalt pavement at KM312.30 – KM314.10 (South bound) was 20th June 2017, wherein the total stretch completed was 1,800m.

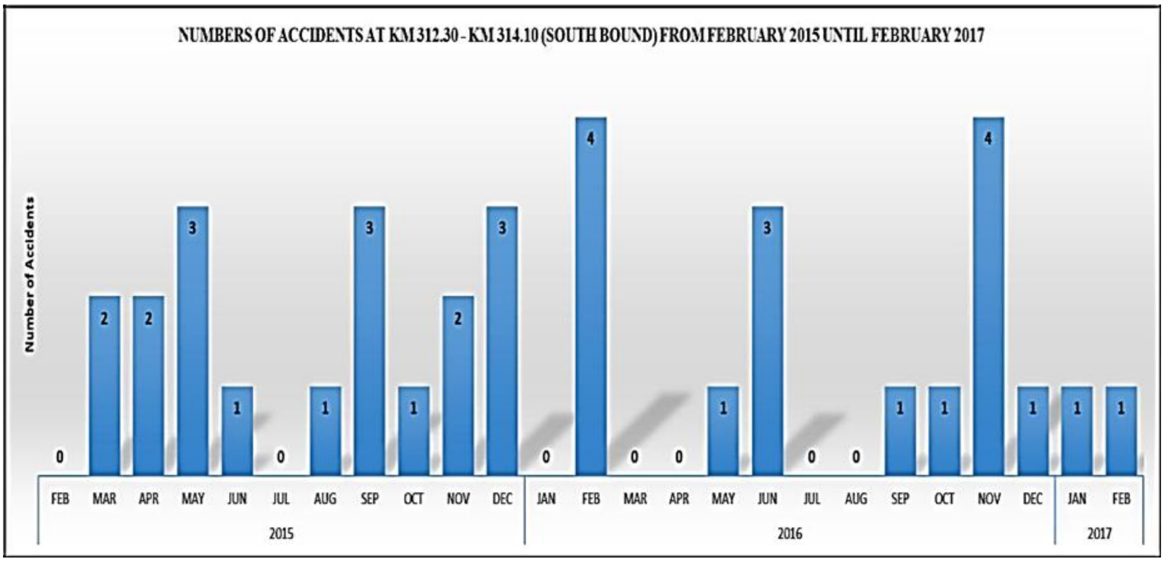

Figure 8: Number of accidents at KM312.30 – KM314.10 (South bound) from February 2015 to February 2017

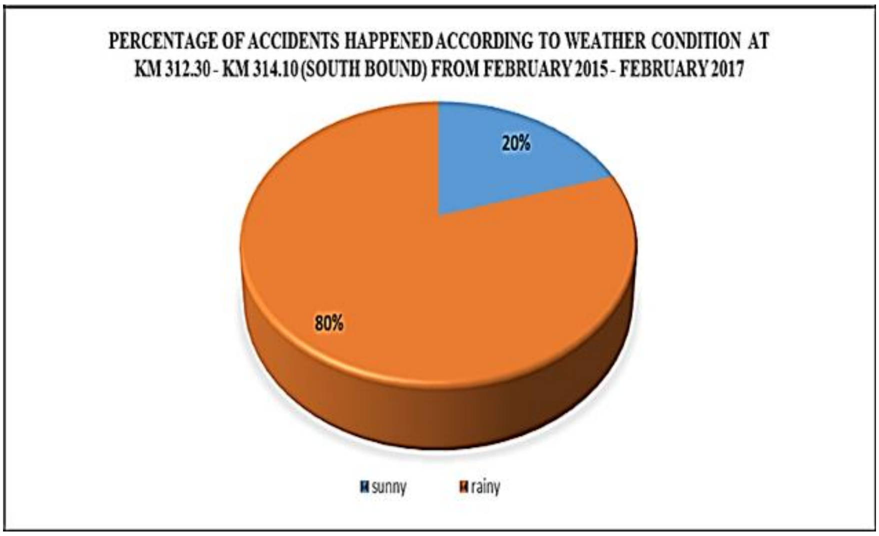

Figure 9: Percentage of accidents with respect to different weather conditions at KM 312.30 – KM 314.10 (South bound) From February 2015 until February 2017

The trend of accidents that happened in accident-prone areas witnessed an increase during the monsoon season, which was from October to December, and sometimes the monsoon season extended even until January (Figure 8). The total number of accidents that happened between February 2015 to February 2017 at KM312.30 – KM314.10 (South bound) were 26. Based on the analysis, 80% (28 accidents) of total accidents happened during the rainy season between KM312.30 – KM314.10 (South bound). This indicates that the environmental factors caused the accidents to occur in the accident-prone areas, either influenced by the weather conditions or the highway conditions. However, based on the raw data on accidents from LPT2SB, it was stated that most of the accidents that happened during rainy weather were recorded as a human factor (Figure 9). The highway patrol was possible to record that because the highway conditions at the location were in good condition, which is no water ponding or any pavement undulations seen appeared. Regardless of human and vehicle factors, wet weather crashes at those accident-prone areas were influenced by environmental factors which could be due to the weather or the highway's condition itself.

3.2 Type of Accident Crashes at the Accident's Prone Area

An analysis to determine the type of crashes at accident-prone areas was conducted, which will reveal the actual cause of the accidents at that particular location. In this study, the accident-prone areas can be defined based on the number of frequent traffic accidents happening in a particular area or place (Yu et al., 2018).

Based on Figure 10, there are one main accident-prone areas, which is KM312.40 (SB) with four (4) cases. The analysis also showed that accidents because of skidding during rainy weather were tremendously high compared to other types of crashes, contributing about 77% (27 accidents) of the total accidents that happened in the accident-prone areas within the two years from February 2015 to February 2017. The second major cause of accident crashed was by losing control which was about 14% (5 cases) which could be caused by sleepy drivers, vehicle problems, or tire explosions. Thus, the analysis of the type of accident crashes in the accident-prone areas revealed that vehicle skidding during rainy weather was the leading cause of accidents in that particular area within the two years. Vehicle skidding or crash during wet weather is mostly influenced by weather, and the performance of pavement surface friction, which is determined by the two parameters, namely skid resistance and texture depth (Yu et al., 2020).

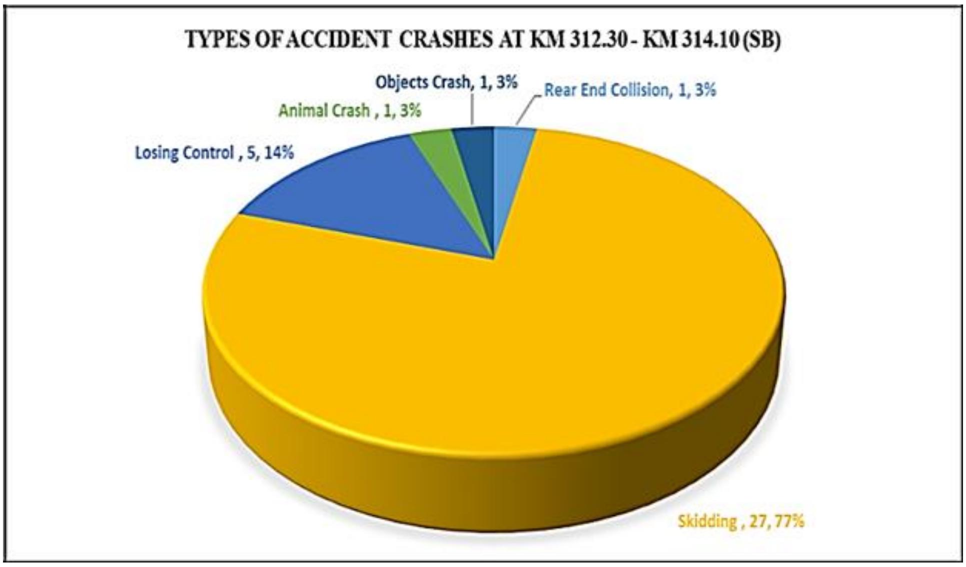

Figure 10: Percentage of type of crashes at KM 312.30 – KM 314.10 (South bound) from February 2015 – February 2017

3.3 Skid Resistance Test

The results from Skid Resistance Test using the British Pendulum Tester before and after laying micro surfacing asphalt along the carriageway (slow lane and fast lane) at the accident-prone areas is illustrated in the histogram graph in order to show the differences between the results.

The Skid Resistance Value (SRV) was increasing in the accident-prone areas after laying micro surfacing asphalt pavement. The Skid Resistance Value (SRV) for the existing highway pavement along the carriageway at the accident-prone areas varied from 38.00 to 44.60. Then, after laying micro surfacing asphalt pavement, the SRV increased from 72.40 to 81.20. At KM312.30 – 314.10 (SB), the average SRV along the carriageway was 40.06, and after laying micro-surfacing, the value increased to 76.91 (Figure 11).

Figure 11: Skid Resistance Test result (before & after) laying Micro Surfacing Asphalt Pavement at the slow lane and fast lane along KM 312.30 – KM 314.10 (South bound)

This result indicated that the average Skid Resistance Value (SRV) at the accident-prone area after laying micro-surfacing had increased. The average SRV for the existing pavement surface was below 46, which means the pavement surface was not in good condition in terms of surface friction and could have caused accidents to happen, especially during wet weather. According to the Jabatan Kerja Raya (JKR), Malaysia, Standard Specification for Road Works: Flexible Pavement, clause 4.13.8.5 (2008) stated that the skid resistance value of the completed material on the carriageway should have a minimum average value of 46 as measured by the SRT pendulum device. Thus, Skid Resistance Value for micro surfacing asphalt pavement at the accident-prone areas was complying with the JKR standard (2008) and displayed an improvement in the pavement surface friction. Therefore, micro-surfacing has positively influenced the safety of driving for highway users.

3.4 Texture Depth Test

A detailed analysis of the texture depth before and after laying micro surfacing asphalt at the accident-prone areas is shown in the histogram in Figure 12. The texture depth showed an increase and improved after laying micro-surfacing asphalt pavement. The texture depth of the existing highway pavement along the carriageway at the accident-prone areas varied between 0.643 - 0.755. After laying micro surfacing asphalt pavement, the texture depth increased from 1.732 to 2.274. The analysis from texture depth test results also indicated that the average Mean Texture Depth (MTD) at the accident-prone areas after laying micro-surfacing increased considerably. At KM312.30 – 314.10 (SB), the average MTD along the carriageway was 0.659, and it increased to 2.135 after laying micro surfacing asphalt pavement. This indicated that the average mean texture Depth (MTD) for the existing pavement surface at the accident-prone areas was below 0.7, except in the stretch between KM394.40 – KM395.80 (SB). According to ASTM E955, the acceptable MTD for a heavy traffic road was not less than 0.7. Thus, the MTD for micro-surfacing asphalt pavement at the accident-prone areas was complying with the ASTM-E955 standards and demonstrated improved pavement surface friction behaviour.

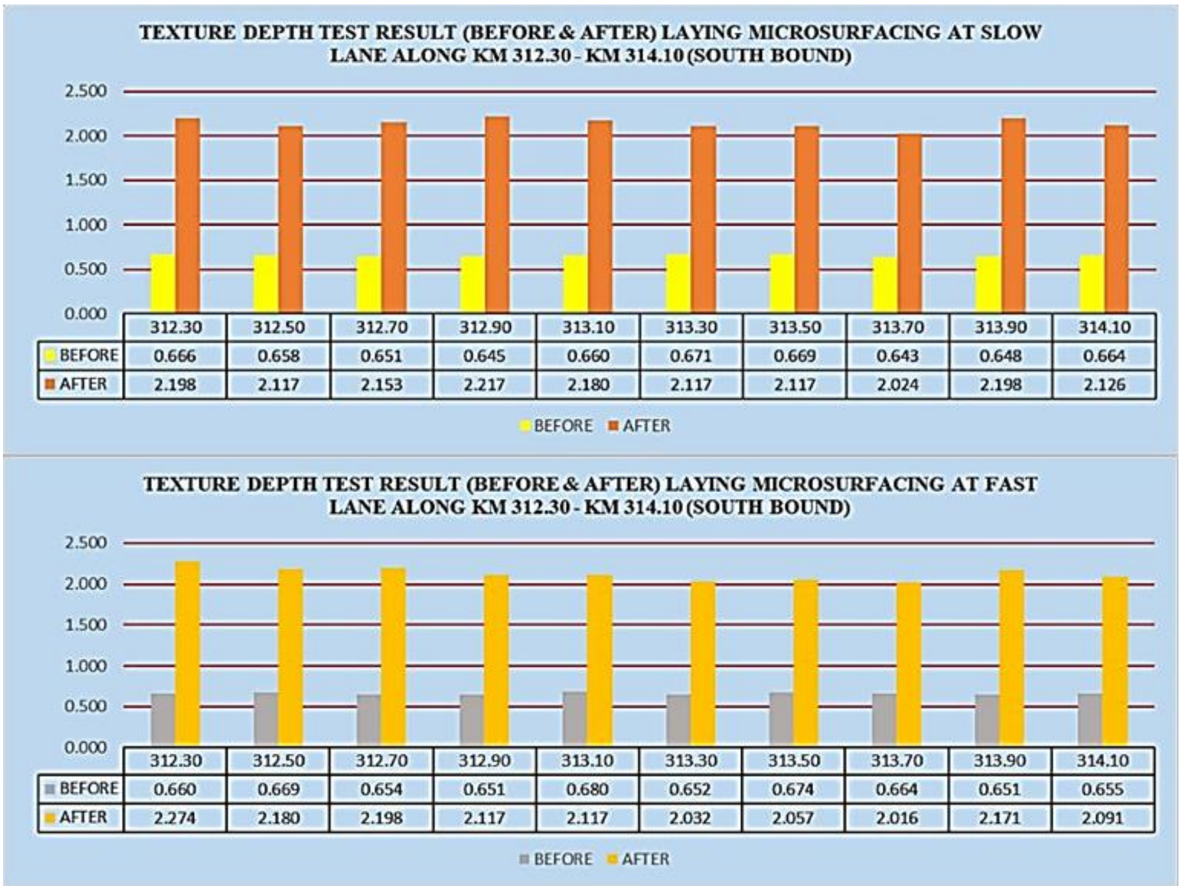

Figure 12: Results of Texture Depth Tests (before & after) laying micro-surfacing asphalt pavement at the slow lane and fast lane along KM 312.30 – KM 314.10 (South bound)

3.5 Statistics of Accident after Laying Micro Surfacing Asphalt Pavement

The study also analysed the rate of accidents after laying micro surfacing asphalt pavement in the accident-prone areas. The analysis will compare the data of accidents that happened only during wet weather conditions, such that it is considered accidents caused only by skidding during rainy weather.

Based on Figure 13, the number of accidents in the accident-prone areas reduced considerably after the execution of micro surfacing asphalt pavement in the site. The rate of accidents during rainy weather at KM 312.30 to KM 314.10 (South bound) reduced up to 100% within 12 months of mitigation measure implementation in the site. The result also depends on traffic volume, regardless of weather conditions. Thus, micro surfacing asphalt pavement as a mitigation measure for the area was successful and effective in saving the life of road users. Micro-surfacing can improve the skid resistance and general surface condition of roads, which can make travel safer (Yu et al., 2020). Micro-surfacing is found to reduce vehicle crashes from about 34 % to 26%, which, however, also depends on traffic volume, regardless of the weather conditions.

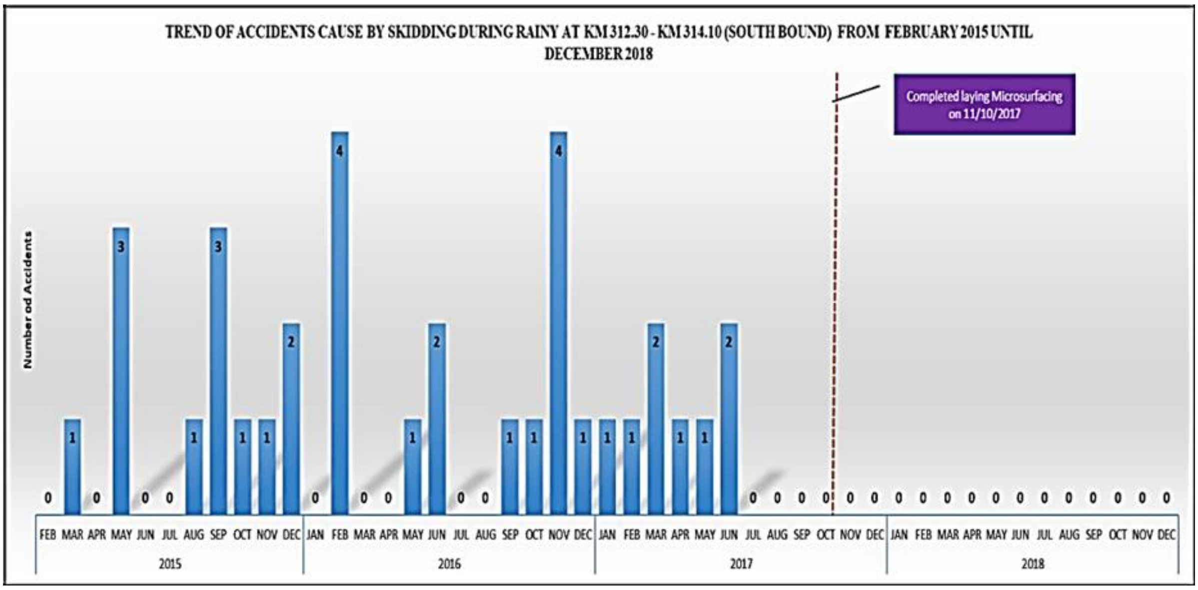

Figure 13: Trend of accidents caused by vehicle skidding during rainy weather at KM312.30 – KM 314.10 (South bound) from February 2015 until December 2018

4.0 CONCLUSION

Road crash investigations have shown significant relationships between the accidents and pavement surface conditions during crashes and ruled out driver’s mistake or vehicle’s failure as a major cause. Thus, the statistics of accidents in the accident-prone areas along East Coast Expressway Phase 2 showed that environmental factors in terms of weather conditions and highway conditions were the most significant contributor to increasing rates of accidents. According to the above results, most types of accident crashes in the accident-prone areas were caused by vehicle skidding during wet weather, which was about 101 accidents (75%) among the total record of 135 accidents. Pavement friction and surface condition were the most common indicators of safety issues related to pavement. Pavement surface properties, such as skid resistance and texture depth, greatly influence the effectiveness of the physical contact of the pavement aggregates with the vehicle's tire (Pranjić et al., 2020).

Micro-surfacing asphalt pavement, which was applied to the East Coast Expressway Phase 2 as a mitigation measure at the accident-prone areas, showed impressive responses. According to the result, the analysis showed that the average Skid Resistance Value (SRV) and average Mean Texture Depth (MTD) increased after laying micro-surfacing asphalt pavement. Based on the key results of the study, the following conclusions are drawn. The rate of accidents in the accident-prone areas was reduced after undertaking mitigation measures at the site. The results highlighted that choosing micro surfacing asphalt pavement as a mitigation measure at the accident-prone areas proved to be successful and efficient, especially in saving lives by improving the skid resistance and texture depth. It is inferred that pavement surface performance in terms of friction is critical in road safety (Pranjić et al., 2020). The weather conditions are also very crucial, being one of the most dominant factors that favour the occurrence of accidents, especially in the east part of Malaysia.

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