INVESTIGATION ON ROAD DAMAGE DUE TO VEHICLE OVERLOADING IN KUALA KRAI FEDERAL ROAD

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DEDICATION

Dedicated to Ummi, Che Eshah Binti Husain & all of my siblings

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ABSTRACT

Networks of paved roads is the dominant infrastructure in the domestic transportation system in Malaysia. Public roads are constantly put under pressure, quite literally, from all the traffic that utilizes them. The longevity of the pavement is highly dependent on two opposing factors; the design thickness of the pavement, and the traffic load, or in simpler words, thick pavements supporting less traffic load will have the maximum lifespan, to a certain extent. Road damage is not an uncommon problem for the authorities and although repairs are done regularly, the effort is practically meaningless if the road continuous receiving overloaded vehicles. This issue has been addressed by many agencies, even in developing countries. However, there is no available study that addresses this issue for Kuala Krai roads. Therefore, this research aims to investigate the effects of vehicle overloading on road damage on Kuala Krai federal roads. The selected study area is the FT008 Kota Bharu - Gua Musang Road, Kelantan. Traffic data was acquired from the Road Traffic Volume Malaysia (RTVM, 2019), traffic count survey, and axle load survey using the weigh-in-motion technology. Based on the available traffic data, the passable pavement layer thickness was calculated and compared to the existing pavement thickness, obtained by field density test, and the standard pavement thickness as set by the Public Works Department. The traffic volume and load survey revealed that commercial vehicles made up 42% of all traffic on the study location, and most of the vehicles that violated the permissible gross vehicle weight (PGVW) were of Classes 3 and 4, despite being infrequent. The calculation of required pavement thickness based on the Equivalence Factor (E.F.) of the surveyed traffic indicated that the existing pavement thickness was highly inadequate for the current traffic load. The pavement thickness was also unsatisfactory based on the standard design requirements by the Public Works Department. Based on the calculation of service life reduction, the pavement service life is expected to be 6 to 7 years shorter than the intended design. In conclusion, the overloading of heavy vehicles and the inadequate pavement thickness has caused major depreciation to the pavement safety and quality, reducing its service life and requiring more rehabilitation works.

ABSTRAK

Jaringan jalan berturap adalah satu infrastruktur asas dalam sistem pengangkutan domestik di Malaysia. Jalan awam dibebani secara berterusan oleh kenderaan yang menggunakannya. Ketahanan jalan berturap bergantung kepada dua faktor bertentangan iaitu; ketebalan jalan dan beban trafik, secara ringkasnya, turapan tebal yang menampung beban yang sedikit akan mempunyai jangka hidup relatif yang panjang. Kerosakan jalan berturap merupakan satu masalah yang tidak baru lagi bagi pihak berkuasa dan walaupun kerja membaik pulih dilakukan secara berkala, usaha tersebut adalah tidak bermakna jika jalan tersebut tetap menerima bebanan trafik berlebihan. Isu ini juga telah diketengahkan oleh pelbagai pihak di negara-negara membangun. Walaubagaimanapun, kajian tersebut belum lagi dilakukan untuk kebanyakan sistem jalan di Malaysia termasuk di negeri Kelantan. Kajian ini bertujuan untuk mengkaji kesan beban trafik ke atas jalan di Kuala Krai. Kawasan kajian yang dipilih adalah Jalan FT008 Kota Bharu – Gua Musang, Kelantan. Data trafik telah didapati daripada *Road Traffic Volume Malaysia 2019* (RTVM 2019), melalui banci lalu lintas dan banci beban gandar menggunakan teknologi *Weigh-in-Motion*. Dengan menggunakan data yang terkumpul, ketebalan turapan jalan yang sesuai telah dikira dan dibandingkan dengan ketebalan sebenar turapan yang didapati melalui *Field Density Test* dan juga dibandingkan menggunakan ketebalan standard yang ditetapkan oleh Jabatan Kerja Raya (JKR). Data banci lalu lintas dan Banci beban gandar menunjukkan 42% kenderaan yang menggunakan jalan tersebut adalah kenderaan komersial dan majoriti kenderaan yang melebihi *Permissible Gross Vehicle Weight* (PGVW) adalah kenderaan Kelas 2, 3 dan 4. Hasil kiraan *Equivalence Factor* (E.F.) menunjukkan ketebalan turapan jalan semasa tidak mampu menampung beban trafik semasa mengikut tetapan JKR. Disebabkan itu, jangka hayat turapan jalan sedia ada diramalkan akan mengalami pengurangan jangka hayat sebanyak 6 ke 7 tahun berbanding rekaan asal. Ini adalah kerana kenderaan berat membawa beban yang melebihi berat telah menyababkan kerosakan yang ketara keatas jalan dan menyebabkan keselamatan dan kualiti jalan merosot.

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LIST OF ABBREVIATIONS

AASHTO	-	American Association of State Highway and Transportation Officials
ADT	-	Average Daily Traffic
ATJ	-	Arahan Teknik (Jalan)
CBR	-	California Bearing Ratio
DCP	-	Dynamic Cone Penetration
E.F.	-	Equivalency Factor
ESA	-	Equivalent Standard Axle
HPU	-	Highway Planning Unit
IRI	-	International Roughness Index
MAL	-	Maximum Axle Load
MEPDG	-	Mechanistic Empirical Pavement Design Guide
PGVW	-	Permissible Gross Vehicle Weight
RTVM	-	Road Traffic Volume Malaysia

LIST OF SYMBOLS

a_n	-	Structural layer coefficient
a_1	-	Structural coefficient for asphalt
a_2	-	Structural coefficient for Sub-base
a_3	-	Structural coefficient for Road base
d_n	-	Thickness of each structure pavement
h_1	-	Surface thickness
h_2	-	Road base thickness
h_3	-	Sub-base thickness
n	-	Service life
P_c	-	Percentage of commercial vehicles
r	-	Annual traffic growth rate
T_A'	-	Corrected equivalent thickness
T_D	-	Designated equivalent thickness
T_E	-	Existing pavement thickness
T_O	-	Overlay thickness
W_{18}	-	Traffic load in basic year

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia is an emerging and developing country, on track of becoming a developed country. Road networks adequacy, in terms of quality and maintenance, of federal roads, state roads, and expressways reflects a major component of the infrastructural readiness of a country to be esteemed as 'developed'. The establishment of satisfactory road facilities plays an important part in the trade and transportation planning, rapidly increasing the pavement infrastructure developments in Malaysia (Nasradeen, 2016). At present, Malaysian road networks consist of three primary classes, which are; tolled expressways (1,821 km), federal roads (17,793 km), and state roads (227,502.398 km), a total of 189,800.100 km of mostly paved roads (Rahmat *et al*., 2019).

Pavements can be classified into two types based on their structural performance, flexible, or rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement having less strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, rigid pavement transfer wheel loads directly to sub-grade soil by flexural strength of the pavement where the pavement works as one solid unit instead of a collection of grain-like structures (e.g. cement concrete roads) (Tom, 2009). The different pavement types are disadvantageous based on specific factors exclusive to their designs, which ultimately bring forth different mode of failures (Hudson *et al*., 2003). Common flexible pavement failures are fatigue cracking, rutting and thermal cracking (Tom, 2009). Hudson *et al.* (2003) also added undulation as one of the major failures. Whereas for the rigid pavement, the major, or rather the only criterion considered for pavement design is the fatigue cracking (Tom, 2009). Other less significant defects rigid pavements may experience are faulting edge, and cracking

(Hudson *et al*., 2003). As mentioned, a comprehensive revision of many factors, other than layering thickness, for example, material and construction requirements, and quality control, is vital in the process of designing of any types of pavement for it will guarantee a resulting pavement structure that performs according to design expectation (Blaschke *et al*., 1993).

Liu (2015) stated, aside from the intrinsic factors, heavy traffic loading is also a consequential determinant to the rate of pavement damage. Heavy vehicle loads on the pavement subject it to high stress, causing damage. However, as mentioned by Gillespie *et al*. (1993), not all heavy vehicle has the same debilitating effects, the damage to the road pavement also depends on wheel loads, number and location of axles, load distributions, number of wheels, tire types, inflation pressure and other factors.

1.2 Problem Statement

Kelantan has 10 districts namely, Kota Bharu, Tanah Merah, Bachok, Machang, Pasir Puteh, Tumpat, Jeli, Kuala Krai, Pasir Mas and Gua Musang. Kuala Krai is a landlocked district in the centre of the state of Kelantan. It can be said that it was located at the heart of Kelantan. It has two governing local authorities which are the Kuala Krai District Council, and the Dabong District Council.

Kuala Krai has a total of 335.72 km of road (222.37 km of state road and 113.35 km of federal road). Most traffic flows through the federal road FT008 Kota Bharu – Gua Musang Road. It spans for 54.25 km total road length across the Kuala Krai District and it is the only road connecting Kota Bharu, Pasir Mas, Tanah Merah, Machang, Tumpat, Pasir Putih, and Jeli to Gua Musang or Kuala Lumpur. It also the route for international shipment transport vehicles, importing goods from Thailand to Malaysia, and exporting goods the other way around. In conclusion the FT008 Kota Bharu – Kuala Krai Road accommodates for various vehicle types, exposing the pavement to heavy vehicles, which might cause road damage over the long run.

The management of FT008 Kota Bharu – Kuala Krai Road falls under the responsibility of Public Work Department (JKR) of Malaysia. The appointed concessionaire, Roadcare (M) Sdn. Bhd. is mandated to do the maintenance work and any other responsibilities related to the maintenance of this this road within right-of-way of the road. Based on previous maintenance record for the past 4 year, a few conservation works have been done through this stretch such as cold in place recycle, mill and pave, regulating and resurface, crumb rubber modified bitumen, subsoil and reconstruction, etc.

Another record covers the reconditioning works of pothole defects along this road for the past four years. A total of 48, 927.25 m^2 asphalt hot mix have been used for 2016, 2017, 2018 and 2019. These maintenance works, and the substantial amount of materials used, however, was for naught as the road continued to sustain damages due to overloading vehicles on the pavement surface. Flexible pavements construction strictly follows regulations set by the JKR, with an expected lifespan of 10 years. Even so, from these records, this road did not achieve the expected the design life. It tends to deteriorate faster, and pavement service life has become shorter.

1.3 Research Objectives

The main goal of this study is to underline the effect of overloaded heavy vehicle to road pavement damage. The following objectives are followed to achieve the goal:

a) To determine the current traffic composition of the road

b) To assess the percentage of overloading vehicle according to different types of vehicle based on local Weight Restriction Order and the damaging factor from equivalency factor (E.F)

c) To calculate the adequacy of existing pavement thickness to withstand current overloading traffic

d) To estimate the reduction of pavement service life due to overloading vehicle.

1.4 Scope of Work and Limitation

In this study, the research scope and limitations are as follows:

a) The case study was conducted at the federal road, FT008 Kota Bharu – Gua Musang Road. It is 54.25 km in length. This case study is focused on the selected stretch of a length of 5 km of flexible pavement road in Laloh

REFERENCES

Aina, S., (2017), *Investigation on Road Damage Due to Vehicle Overloading in Ipoh State Road.* Masters Thesis, University Teknologi Malaysia, Skudai

American Association of State Highway and Transportation Officials. (Byron, 2008), Mechanistic-Empirical Pavement Design Guide MEPDG. *A Manual of Practice*. Washington D.C.: AASHTO Publications.

Ayat, M., (2013). Pavement and Alignment Design of a New Rural Road in the Province of Bologna. *Alma Mater Studiorum – Universita di Bologna.* Available at: https://core.ac.uk/download/pdf/31156088.pdf.

Aziz, N.A., Matori, M.Y., Hussain, M.Z., Azmi, A., Sufian, Z., (2010). Challenges in design and construction of cold in-place recycling pavements in Malaysia. *24th ARRB Conference.* October 2010. Melbourne, Australia.

Bai, Y., Schrock, S.D., Mulinazzi, T.E., Hou, W., Liu, C., Firman, Umar., (2010). Estimating Highway Pavement Damage Costs Attributed to Truck Traffic. *Final Reports & Technical Briefs from Mid-America Transportation Center.* Available at https://digitalcommons.unl.edu /matcreports/55/.

Blaschke, B., Afferton, K.C., Willet, T., (1993*) AASHTO Guide Design of Pavement Structures 1993*, Washington D.C.: American Association of State Highway and Transportation Officials.

Gillespie T.D., Karamihas S.M., Cebon D., Sayers M.W., Nasim M.A., Hansen W. and N. Ehsan (1993), Effects of Heavy Vehicles Characteristic on Pavement Response and Performance, *National Cooperative Highway Research Program Report 353, Transportation Research Board, National Research Council, Washington D.C.*, pp. 150.

Hanif, S., Ahmed, A., Saeed, T.U., Bai, Q., (2016). Estimation of Pavement Damage Cost for Establishing Equitable Road Use Fee for Commercial Vehicles – An Exploratory Empirical Analysis. *1st International Conference on Transportation Infrastructure and Materials.*

Hesp, S.A.M., Soleimani, A., Subramani, S., Phillips, T., Smith, D., Marks, P., Tam, K.K., (2008). Asphalt pavement cracking: analysis of extraordinary life cycle variability in eastern northeastern Ontario. *International Journal of Pavement Engineering,* 10(3), pp. 209-227. doi: 10.1080/10298430802343169.

Highway Planning Unit (2015), *Road Traffic Volume Malaysia*, Publication, Ministry of Works Malaysia, Highway Planning Division, Kuala Lumpur.

HRB (1962), *The ASSHO Road Test, Special Report 61A, 61C, 61E*. Washington D.C.: Highway Research Board Publication.

Hudson W.R., Monismith C.L., Dougan C.E. and Visser W., (2003). Use Performance Management System Data for Monitoring Performance: Example with Superpave, *Transportation Research Records 1853, TRB, Washington D.C.*

Jabatan Kerja Raya (2013), *Manual for the Structural Design of Flexible Pavement*. Kuala Lumpur: Jabatan Kerja Raya Malaysia

Jabatan Kerja Raya Malaysia (1993), *Manual on Pavement Design*. Kuala Lumpur: Jabatan Kerja Raya Malaysia

Kinder, D.F., Lay, M.G., (1988). Review of the Fourth Power Law. *Australian Research Board Internal Report; Air 000-248-Untraced series.* Berkeley: UC Berkeley Transportation Library.

Kordi, N.E., Endut, I.R., Wahab, M.Y., Baharom, B., (2012). The relationship between traffic volume of heavy vehicles and the performance of Malaysia federal routes one (FT01) in Selangor: A case study. *2012 IEEE Business, Engineering & Industrial Applications Colloquium (BEIAC),* pp. 430-434. doi: 10.1109/BEIAC.2012.6226097

Kumar, P., Gupta, A., (2010) Case studies of failures of bituminous pavements, *Compendium of Papers from the First International Conference of Pavement Preservation*, 7(52), pp. 505-518

Langer, I.A.A., (2011), Analysis of Road Damage Due to Over Loading (Case Study: Demak-Trengguli Arterial Road, Central Java Province, Indonesia, PhD Thesis, Department of Civil Engineering University of Diponegoro Samarang, Indonesia.

Liu, J., (2015), Research on the damage of heavy vehicles to the pavement, *3rd International Conference on Management, Education, Information and Control*. September 2015. Nanchang, China

Livneh, M. (1987), Correlation Between the DCP and CBR Values. *Transportation Research Institute.* Haifa: Transportation Research Institute Publication 87-065.

Malaysia (2013), *Act 333, Road Transport Act 1987.*

Nasradeen, A.K., Madun, A., Rohani, M.M., Ambak, K., Siang, A.J., Bazli, M.F., (2020), Ground Vibration Analysis at Speed Humps for Heavy Vehicle: A Case Study in Batu Pahat, Johor. *Journal of Safety, Health and Ergonomics*, 1(2), 1-5.

National Transport Research Centre (2018). *Practices and Issues.* Geometric Loadings of Good Vehicles. Government of Pakistan: Ministry of Communication. Available at: http://www.ntrc.gov.pk/ntrc_studies/NTRC%20Geometric%20loading%20of%20vehicles%20in%20Pakistan.pdf (Accessed: 26 June 2020)

Oppong-Acheampong, K., (2016). A study on factors that contribute to pavement deterioration on the Mampong Arterial (Suame Roundabout – Pankrono Road). *Institutional Repository for Knust.*

Punjab Roads and Bridges Development Board (2008) Field Density Test by Sand Replacement Method. *Tests on Soils*. Available at: http://www.prbdb.gov.in/files/Quality%20Control%20Training/Tests (Accessed: 15 July 2020)

Rahmat, N.A., Hassan, N.A., Jaya, R.P., Satar, M.K.I., Azahar, M., Ismail, S., Hainin, M.R., (2019). Effect of compaction temperature on the performance of dense-graded asphalt mixture. *IOP Conference Series: Earth and Environmental Science.* doi: 10.1088/1755-1315/244/1/012012.

Tom, V.M., (2009) *Introduction to pavement design.* Lecture notes in Transportation Systems Engineering.

Transport and Road Research Laboratory (1969), *Instruction for using the Portable Skid Resistance Tester*, TRRL Road Note 27, London: Ministry of Transport

Transport and Road Research Laboratory (1978), *Guide to the Measurement of Axle Load in Developing Countries using Portable Weight Bridge*, TRRL Road Note 40. London: Her Majesty's Stationery Office.

Webster, S.L., H. Grau and T.P. Williams (1992). Description and Application of Dual Mass Dynamic Cone Penetrometer. *Instruction Report GL-92-3.* U.S. Army Engineers Waterways Experimental Station.

Yu H.T., Khazanovich L., Darter M.L. and Ardani A. (1998), Analysis of Concrete Pavement Responses to Temperature and Wheel Load Measured from Instrumented Slabs. *Journal of Transportation Research Record*, 1639, pp. 94-101. doi: 10.3141/1639-10