

Driving Mode at Pothole-Subsidence Pavement

Based on Wheel Path & Speed

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Abstract. The pavement distress has considerable influence with drivers. Considering the fact that the forms of asphalt pavement potholes, subsidence and cement pavement potholes (collectively defined as pavement pothole-subsidence) are similar and they can influence traffic flow significantly, we put forward to use indexes such as Tangential Diameter Length, Normal Diameter Length, Depth, Lateral distance, etc to describe the characteristics of pothole-subsidence. According to different wheel paths & speed, driving modes was classified into several types, influences of various pothole-subsidence on driving mode and speed was analyzed. By the research, we get that Pothole-Subsidence Pavement significantly influenced the variation of vehicle trajectory, and the relationship between driving speed and driving mode choosing is correlative tightly, the main driving mode choosing influence factor are lane number, driving speed, traffic and the PS' size and figure.

Introduction

The phenomena, such as overloading vehicle and pavement wear fatigue, are inevitable. Unlike shaped crack or dislocation, slight damage of lower degree or less distinctive such as asphalt pavement potholes, subsidence and cement pavement potholes are more likely to be ignored, which however, can influence the safety and efficiency of vehicle operation in various degrees. There exist a great many studies on the emergence and maintenance of asphalt pavement potholes, subsidence and cement pavement pothole at home or abroad^[1-3], yet theories about its influence on driving behavior, vehicle trajectory and operation mode of traffic flow are rarely published. On the base of analyzing different aspects such as the figure and location of road potholes or subsidence as well as traffic flow we analyzed their influence on driving mode and traffic flow, thus we provided theoretical basis for further study of actual urban road capacity and mark-setting under the circumstance of defective pavement.

Definition of pavement pothole and shape characterization indexes

According to *Urban road maintenance technical specifications* the definitions and concept definitions of asphalt pavement pothole, subsidence and cement pavement pothole are as follows^[4]:

Definitions.(1) Asphalt pavement pothole: pothole formed after the loss of pavement materials, belonging to damage of loose class.

(2) Asphalt pavement subsidence: partial pavement subsidence, belonging to damage of deformation.

(3) Cement pavement pothole: holes appeared on the surface of cement panel whose diameters ranged from 25 to 100mm while depths ranged from 1 to 50mm.

Concept Definitions. Asphalt pavement pothole: when the depth of certain pothole reaches 20mm and its area reaches 0.04m^2 it can be demarcated as pothole. For gathered small area pothole, if their distances are less than 0.2m they should be measured together.

Asphalt pavement subsidence: when there are vertical deformations of roadbed and asphalt pavement and the depth of pavement concave is above 30mm it can be demarcated as subsidence.

Cement pavement pothole: partial potholes whose areas are above 0.01m^2 formed due to the fall of coarse aggregate on cement pavement can be demarcated as pothole.

For the convenience of research, we collectively define asphalt pavement pothole, asphalt pavement subsidence and Cement pavement pothole as pavement pothole-subsidence(**PS** in abbreviation).

Characterization indexes about the figure of **PS** are as follows, shown as fig.1.:

Tangential diameter length (L): Width of **PS** parallel to the driving direction, m

Normal diameter length (W): Width of **PS** perpendicular to the driving direction, m

Depth (D): Height difference between road surface and the innermost of the **PS**, m

Center distance (m_c): Distance between the entrance and the innermost of the **PS**. According to the driving direction, it can be divided into two categories, one is approach center distance (m_c), the other is depart center distance (m_g).

Driving modes on **PS** road section

There are three stages if drivers' discover of the **PS**s: Recognition, Judgment and Execution. According to wheel pathes, driving modes can be classified into three types, shown as fig.2:

Mode 1: Drivers failed to notice **PS** or drivers continued their original driving route. This phenomenon results from following factors:

- (1) Drivers' neglect of **PS**s
- (2) Discover the **PS**, drivers predicated that tires won't run into **PS**s along original driving route
- (3) Discover the **PS** and the fact that tires may run into **PS** along original driving route, drivers determined to pass through **PS**s by means of deceleration.

Mode 2: Drivers discover the **PS**s and its badly influence, so they turned the steering wheel and altered their driving route. Because of the interference of vehicles adjacent sides, it may be impossible to merge into adjacent lanes or perhaps it is not necessary to alter lanes, drivers still drive along original lane or occupied a little part of adjacent lane after slight swing of driving direction, and then back to normal. It may lead to two kinds of consequences as follows:

- (1) The distance to the **PS**s may be too short for drivers to adjust driving direction dramatically, or, traffic densities on both sides are too high for drivers to merge into adjacent lanes. Therefore vehicles still run into **PS**s after altering directions.
- (2) Vehicles changing direction, and then pass through the road section without running into **PS**s.

Mode 3: Drivers discover the **PS**s which influence badly on driving, and it is available to merge into nearby lanes, drivers merge into adjacent lanes and then came back to normal driving as before.

- (1) The distance to the **PS**s may be too short for drivers to adjust driving direction dramatically vehicles may still run into **PS**s at the time of changing lanes or after merging into adjacent lanes
- (2) After changing lane vehicles pass though the road section smoothly instead of running into **PS**s.

Research and analysis based on wheel path

We choose 10 **PS**s located in different streets in Harbin for field measurement, which include Huashan Rd. (3), Caiyi Str.(3), Huanghe Rd.(1), Ganshui Rd., Xidazhi Rd.(1) and Zhujiang Rd.(1) and the influence on the road traffic operation was recorded on video. State indicators of investigated **PS** are shown in table1.

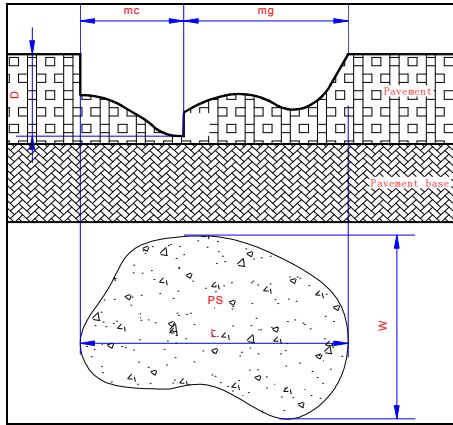


Fig.1 Schematic plot of PS pavement

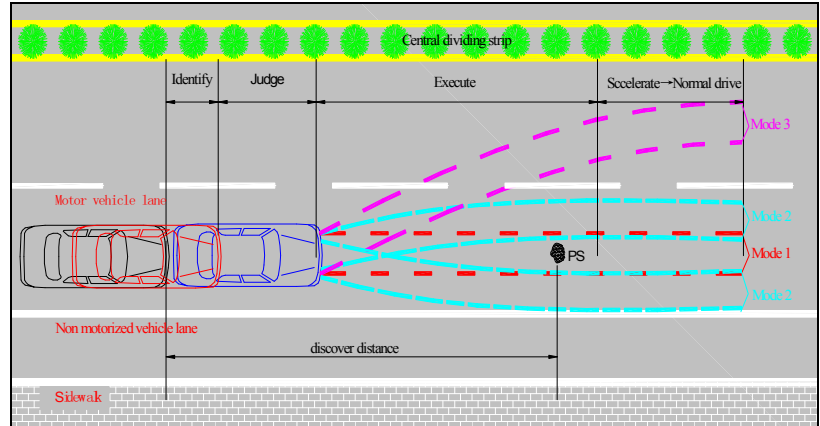


Fig.2 Wheel path of each Driving mode

Table1 State indicators of investigated PS

No.	Location	Lane No.	Direction	L (m)	W (m)	D (m)	m _c (m)	m _g (m)
1	Huashan Rd., 40m to the north of Pujiang Rd.	6	North	0.72	1.25	0.06	0.35	0.37
2	Huanghe Rd., 50m to the west of Huashan Rd.	6	West	3.75	0.83	0.03	1.12	2.63
3	Xidazhi Rd., 50m to the south of Jiaohua Str.	6	North	0.68	0.40	0.07	0.35	0.33
4	Xuanqing Str., 30m to the south of Pinggong Str.	6	North	0.22	0.38	0.04	0.10	0.12
5	Huanshan Rd., 80m to the south of Huanghe Rd.	6	North	0.82	0.86	0.05	0.34	0.48
6	Caiyi Str., 30m to the north of Liushun Str.	2	South	1.38	3.22	0.09	0.70	0.68
7	Caiyi Str., 50m to the south of Liushun Str.	2	South	0.42	0.58	0.12	0.23	0.19
8	Caiyi Str., 150m to the north of Gongbin Rd.	2	North	0.15	0.35	0.08	0.08	0.07
9	Ganshui Rd., 30m to the west of Tianshun Str.	4	East	0.48	0.35	0.08	0.20	0.28
10	Zhujiang Rd., 200m to the west of Songshan Rd.	4	West	0.88	0.82	0.02	0.38	0.50

(2) Traffic survey on PS pavement

We adopt AutoScope-2004 video detection system aided by artificial judging to investigate in the surveyed road section. And we acquired information including traffic volume, lane occupation ratio, vehicle types, speed, headway, vehicle density and so on. The survey result is shown as table2.

Table2 The Traffic & Speed in each mode

NO.	Traffic(pcu/h)				Original	Average Speed (km/h)				S _i (%)
	M1	M2	M3	Total		At the SP spot				
						M1	M2	M3	Total	
1	75	177	130	382	33	16.41	24.97	28.88	24.62	24.62
2	71	197	112	380	43	14.29	36.20	40.40	33.34	33.34
3	103	190	84	377	36	28.70	32.17	32.37	31.26	31.26
4	76	84	9	169	35	28.28	29.58	30.25	29.03	29.03
5	57	246	27	330	24	15.97	18.05	21.49	17.97	17.97
6	2	26	75	103	22	8.88	9.89	16.05	14.36	14.36
7	14	59	35	108	20	14.14	16.27	17.95	16.54	16.54
8	33	60	14	107	26	20.40	23.09	23.76	22.35	22.35
9	22	108	14	144	21	15.60	16.77	17.41	16.65	16.65
10	56	180	34	270	28	11.21	20.64	22.74	18.95	18.95

Note: Where M_i is mode *i*; Traffic is only the traffic on the PS lane in an hour; S_i is the rate of decrease speed, $S_i = 1 - V_o / V_a$ Where V_o is the original speed; All cars average speed at the PS spot V_a is:

$$V_a = \frac{\sum_{i=1}^n T_i * V_i}{\sum_{i=1}^n T_i}, T_i \text{ is traffic about mode } i; V_i \text{ is average speed about mode } i \text{ at the PS spot, } n \text{ is the mode number.}$$

Judging from the driving mode, *PSs* significantly influenced the variation of vehicle trajectory. Almost 78.5 percent of the vehicles altered their driving direction, and 56% drivers chose slightly altering as mode 2 while 22.5% drivers chose changing lanes as mode 3.

As to the decrease of speed, we found that *PSs* can obviously bring down the driving speed whose average rate of descent reached 22.2%. In practical terms, speed descents for mode 1, whose rate of descent reached 50.3%, are more distinct than the rest two modes, while relatively the rates of descent for mode 2 and 3 are only 24.3% and 12.5%. Through observation, we made a conclusion on the cause of speed descent, that is a great many vehicles ran into *PSs* and drivers slowed down to ease the turbulence occurring at the same time, and there are still plenty of drivers decelerated for fear of running into *PSs*; Percentage of vehicles running into *PSs* are relatively low for mode 2 and 3 and most vehicles kept larger safety space between the wheels and the *PSs*.

Judging from the relation between characterization index and driving mode along with speed, the influence of *PSs* on vehicle operation can't be determined simply by characterization index, it's the comprehensive reaction of various aspects such as figures and location of the *PSs*, driving speed, driver characteristics, etc. From the curves of each single factor and speed descent, we concluded that there exist significant differences between each curve, while curves of normal diameter length and speed descent are most similar to each other, which indicates that normal diameter length is the most important factors for speed descent on condition that there are slight differences in other factors. The conclusion is shown in fig.3.

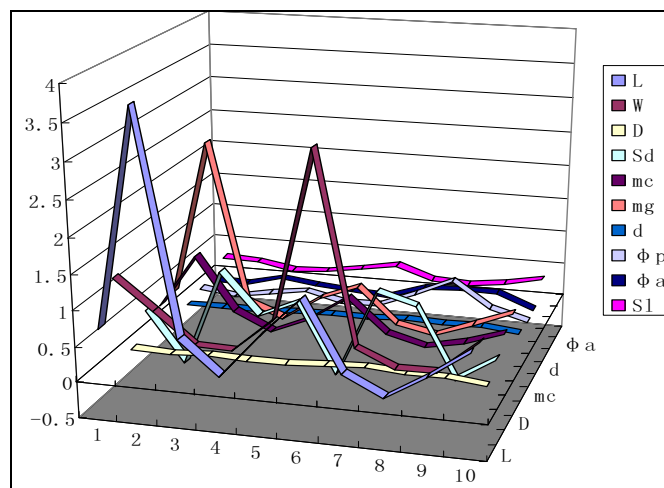


Fig.3 Curves of factors and speed descent rate

Research and analysis based on speed

At the different speed, the vehicle's driving mode is distinguishing. As the speed rising, the traffic in mode1 and mode2 cut down, and the vehicle driving in mode4 rise, which is shown in Table3 and fig.4, and dashed lines in figure 4 are trendlines of M1, M2 and M3.

The reasons are (1) The car running in branch road has lower speed, and the most branch road only has 2 lanes, if its driver discovers the *PS* and he wants to change driving lane, he has to stem against, and if the retrorse lane is busy, there is no choice to driving in mode 3; (2) the car gets across the *PS* running in low speed is more comfortable than high speed.

Conclusions

- (1) *PSs* significantly influenced the variation of vehicle trajectory, 78.5 percent of the vehicles altered their driving direction, and 56% drivers slightly altered driving direction while 22.5% drivers changed lanes, and the average rate of speed descent is over 20%.
- (2) *PSs* can obviously bring down the driving speed whose average rate of descent is more than 20%, and speed descent in mode 1 is the most obvious of three modes.

(3) The influence of *PSs* on vehicle operation can't be determined simply by characterization index, it's the comprehensive reaction of various aspects such as figures and location of the *PSs*, driving speed, driver characteristics, etc. Relatively speaking, normal diameter length can be the most important factors for speed descent.

(4) The relationship between driving speed and driving mode choosing is correlative tightly, the main driving mode choosing influence factor are lane number, driving speed, traffic and the *PS*' size and figure.

Table3 The relation between speed and mode choosing

NO.	Speed Original (km/h)	Total(veh)	Traffic in each Mode					
			M1		M2		M3	
			Traffic(veh)	Rate(%)	Traffic(veh)	Rate(%)	Traffic(veh)	Rate(%)
1	0-20	324	83	25.6	193	59.6	48	14.8
2	20-40	892	265	29.7	421	47.2	206	23.1
3	40-60	765	168	22.0	356	46.5	241	31.5
4	60-80	341	72	21.1	176	51.6	93	27.3
5	>80	48	9	18.8	19	39.6	20	41.7

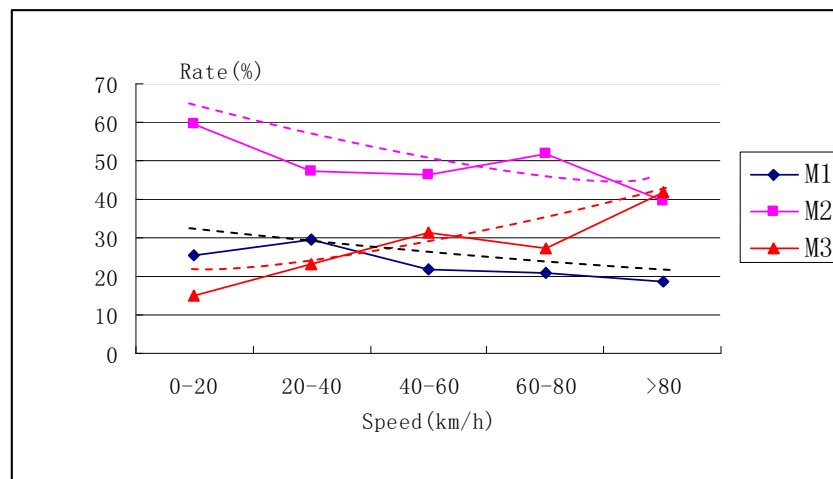


Fig.4 The relationship between Speed and mode choosing

Acknowledgements

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