

Holes in the Pavement—An Assessment of Their Influence on Safety

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ABSTRACT

A hole must be relatively large to constitute a significant safety influence when rim or tire damage are the guiding criteria. A hole must be in excess of 60 in. long and 3 in. deep to constitute a threat to the smallest automobiles at highway speeds in excess of 40 mph. On urban streets, with traffic speeds as low as 20 mph, holes must still be greater than 30 in. long and greater than 3 in. deep to have the potential of damaging tires and rims, or both. Damage to tires and rims, with the associated potential for a tire blowout, is the only significant safety-related influence of holes identified in this study. Holes are atypical of most highway surface discontinuities in that the lower the vehicle speed, the greater the potential for causing damage. Problems can arise if a driver reacts to the hole inappropriately. For example, it is counterproductive to react to a hole in the vehicle's path by braking or extreme cornering. In general, a hole of a given size is more likely to cause damage if speed is reduced. Losses of control can occur if extreme braking is produced at highway speed. Extreme cornering can have two results: (a) if a driver reacts with a large steering input to avoid a hole, he may produce a loss of control on a low friction surface; and (b) the vehicle may be put in a hazardous position with respect to other traffic. It is probably the latter that accounts for most of the accidents where holes are identified as contributing factors.

The nature of a hole (also known as "pothole" and "chuck hole") is to be hard on tires, vehicles, and drivers' tempers, but are holes really a significant direct threat to safety, or is their influence on safety highly inflated by many accident reports reflecting driver frustrations and excuses?

Accident reports state that "holes" are a causative factor in many accidents. In 1976 Ivey and Griffin (1) reported a rank ordering of various types of roadway disturbances based on 15,968 accidents in North Carolina. Of these, the narratives of 566 stated that the accident was either caused or aggravated by some kind of roadway disturbance, for example, holes, ruts, soft shoulders, or water. Hole was mentioned in 59 reports ranking it 5th of 19 disturbances behind the key words water, dropped, soft, curb, and edge. In a Delphi ordering developed by the same authors, holes appeared more important to the drivers of wrecked vehicles in North Carolina than they did to the engineers involved in the Delphi study.

It appears clear, whether justified or not, that holes are perceived to be a significant threat to

safety. It is also clear that the perception of the public is not shared by many engineers with significant knowledge of vehicle handling and stability characteristics. One way of more accurately defining the problem is by controlled vehicle-hole interactive tests. The experiments conducted as part of this project reflect an effort to separate folklore, personal perceptions, and societal opinion from fact.

TEST PROGRAM

A comprehensive test program was developed to evaluate the safety-related effects of roadway surface discontinuities in the form of holes in pavement, commonly referred to as potholes. Because there is an infinite number of pothole shape, area, and depth combinations, and a large number of vehicle suspension system and tire combinations, a program to examine all conceivable combinations was deemed impractical. The research approach here was to determine a worst-case condition, or a condition that would produce a definite safety hazard. This condition was defined as an upper boundary and sublimit tests were performed to evaluate the potential influence on safety.

Hazardous Condition Determination

Knowing the drop rate of various wheel and suspension systems and the initial ride height of the rim (bottom of the rim to the ground distance), it is possible to predict the minimum length and depth of a pothole (with a relatively square edge) that will produce a possible hazardous condition at any particular speed.

To test the theoretical methods developed to determine safe pothole sizes, several runs were made at 20 mph using the mini-compact and intermediate sized vehicles, dropping the left wheels into the 36-in. diameter test hole set to a depth of 6 in. The speed of 20 mph was arbitrarily selected as a lower limit for this study because it was believed that any lower speeds should not produce safety-related problems. This speed then becomes the worst-case condition because lower speeds should not produce significant problems and higher speeds do not allow the wheels to drop as far for a given length.

It was found during field and test track testing that directional stability was not affected by impacting single holes up to and including 3 ft in diameter and 6 in. deep. According to the test driver, even the run that bent the rim of the intermediate vehicle did not change the vehicle path or force the steering wheel to turn.

The chart shown in Figure 1 is conservative in that the square edge hole is the most critical of the hole edge geometries. Three bands of safety are shown based on the four test vehicles evaluated. The first band, left and lower, defines hole length and depths referred to as being reasonably safe or where a prudent driver of a reasonably maintained vehicle would experience no significant problem in traversing the hole. The middle band, which is bounded by

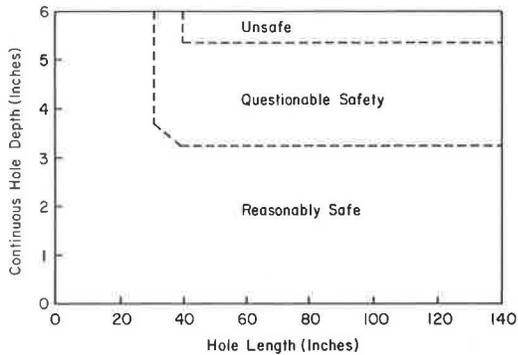


FIGURE 1 Pothole safety as a function of size.

the upper and lower extremes of vehicles tested, represents a questionable safety area where a vehicle could sustain tire, rim, or suspension damage when traversing a hole with the defined dimensions. Finally, the unsafe band defines length-depth combinations that could produce a hazardous condition for any of the four vehicles tested.

Limitations of Test Program

Although the choice of vehicles would appear adequate to define a fairly wide spectrum of vehicle characteristics, this has not been experimentally verified. Parameters such as inertial properties, spring stiffness, and tire stiffness should be considered in order to objectively evaluate the spectrum of vehicles encompassed. Other factors such as vehicle loading and the influence on vehicles other than four-wheeled passenger vehicles were not considered. As with snowflakes, there are probably no two potholes alike in terms of shapes, edge slopes, and bottom contours. This study used a definable square edge with vertical sides and a level bottom. This approach provided insight into a worst-case situation that may encompass only a small number of real world potholes. It does, however, permit conservative safety predictions because any sloping of the sides will only produce a safer condition for a given-size hole.

CONCLUSION

It is apparent that a hole must be relatively large to constitute a significant safety influence when rim or tire damage are the guiding criteria. A hole must be in excess of 60 in. long and 3 in. deep to constitute a threat to the smallest automobiles at highway speeds in excess of 40 mph. On urban streets, with traffic speeds as low as 20 mph, holes must still be greater than 30 in. long and greater than 3 in. deep to have the potential of damaging tires and rims, or both.

Damage to tires and rims, with the associated potential for a tire blowout, is the only significant safety-related influence of holes identified in this study. Holes are atypical of most highway surface discontinuities in that the lower the vehicle speed, the greater the potential for causing damage.

Problems can arise if a driver reacts to the hole inappropriately. For example, it is counterproductive to react to a hole in the vehicle's path by braking or extreme cornering. In general, a given-size hole is more likely to cause damage if speed is reduced. Losses of control can occur if extreme braking is produced at highway speed. Extreme cornering can have two results: (a) if a driver reacts with a large steering input to avoid a hole he may produce a loss of control on a low-friction surface; and (b) he may put his vehicle in a hazardous position with respect to other traffic. In the authors' opinion, it is probably the latter that accounts for most of the accidents where holes are identified as contributing factors.

The purpose of this work is certainly not to conclude that holes in highway surfaces should be tolerated. The many disadvantages of these flaws dictate their elimination within the bound of financial constraints. The purpose is to put the safety influence of holes into a reasonable perspective, so that maintenance activities can be assigned the appropriate priority.

REFERENCE

1. Don L. Ivey and Lindsay I. Griffin III. Driver Vehicle Reaction to Road Surface Discontinuities and Failures. Proc., International FISITA Conference, Tokyo, 1975.