Evaluation of the stability of vehicles during floods
State of the art review

Ricardo A. Bocanegra (ribovi@doctor.upv.es), Francisco J. Vallés and Félix Francés

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

INTRODUCTION

Floods can significantly affect vehicles, which in turn can increase the negative effects of floods when they are washed away by the water flow and become debris that impact existing infrastructure and buildings and clog hydraulic works. In cities the highest number of deaths during floods occurs inside cars.

Few studies have been conducted about this topic. Most of the available studies were developed in 60´s y 70´s and some theoretical analyzes of the 90's are available. It is considered that these studies are not representative of the conditions of the current cars.

STABILITY OF VEHICLES DURING FLOODS

The loss of stability of a vehicle can be generated by the hydrodynamic mechanisms of floating and sliding (Arrighi et al., 2016). The loss of floating stability occurs when the buoyancy and the lift effect exceed the weight of the vehicle.

The loss of sliding stability occurs when the drag force exerted by the flow exceeds the frictional force, which depends on the coefficient of friction between the tires and the wet surface of the road.

An additional failure mechanism is represented by toppling, which seems to occur only when the vehicles have already been dragged by the flow or have floated and find an irregular terrain (Shand et al., 2011).

Available methodologies for determining the stability of the vehicles differ from each other in the way they approach the problem, especially with regard to the water tightness of the vehicles.

AVAILABLE METHODOLOGIES

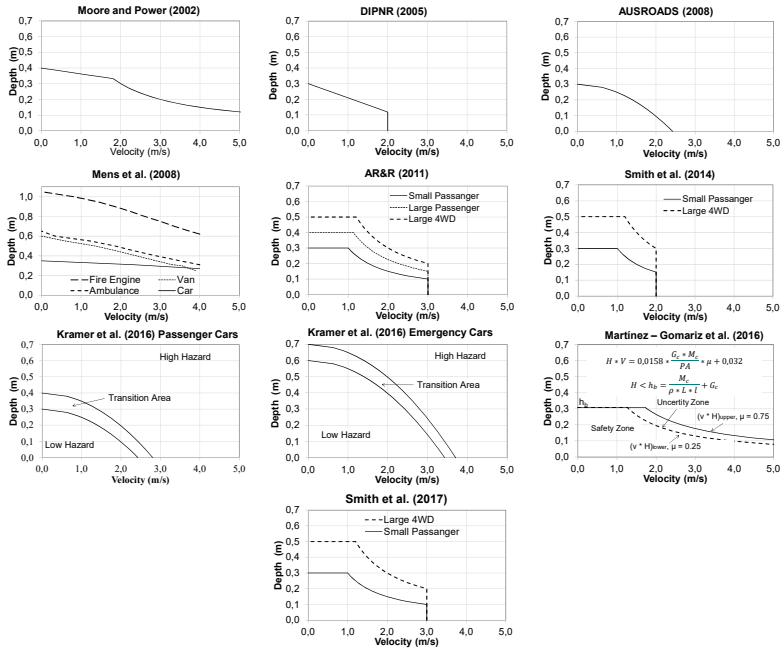


Figure 1. Methodologies that consider the watertightness of cars

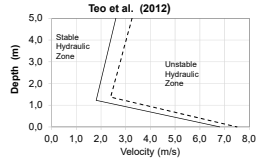


Figure 2. Methodology that considers the non-watertightness of cars

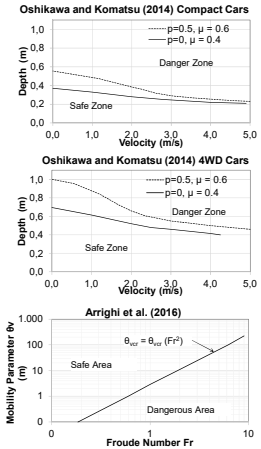


Figure 3. Methodologies that consider watertightness and non-watertightness of cars

COMPARISON OF METHODOLOGIES

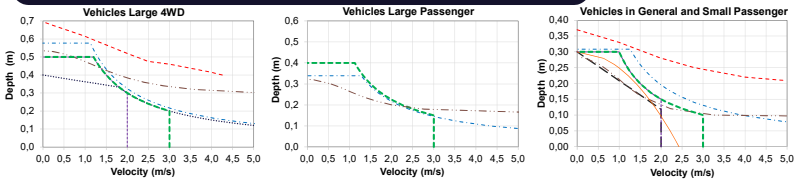


Figure 4. Methodologies that consider the watertightness of cars

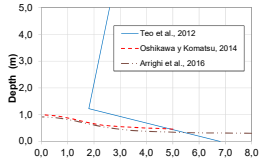
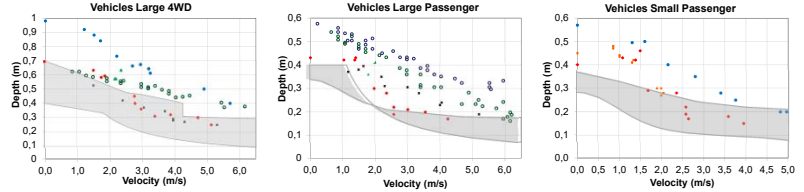


Figure 5. Methodologies that consider the non-watertightness of cars

COMPARISON OF METHODOLOGIES WITH EXPERIMENTAL DATA



Author	Class of Vehicle		
	Large 4WD	Large Passenger	Small Passenger
Shu et al. (2011)	○ Volvo XC90	○ Ford Transit ○ Ford Focus	
Toda et al. (2013)	▲ Minivan	▲ Sedan	
Xia et al. (2013)	✖ Audi Q7	✖ Honda Accord	
Kramer et al. (2016)			X VW Golf III
Martínez et al. (2017)	◆ Mercedes GS5	◆ Mercedes GLA	◆ Mini Cooper
Smith et al. (2017)	● Nissan Pat. GRII		● Toyota Yaris

Range in which the proposed stability thresholds fluctuate

Figure 6. Comparison of stability thresholds with experimental data. Watertight vehicles

CONCLUSIONS

Several methodologies have been developed to determine vehicles stability thresholds in floods. These thresholds vary in a relatively wide range, due to the differences in the way of approaching the water tightness of the vehicles and in the decision criteria adopted to determine the stability of the cars.

All the methodologies developed have made several simplifications. Some of the most important are the following: (i) only cars at rest have been considered; (ii) most of the experiments have been developed considering a horizontal slope; (iii) the coefficient of friction between the tires and the road has not been studied in depth; (iv) only tests have been performed using a controlled flow in laboratory channels; (v) the majority of experimental studies have been carried out in scale models.

New research is required that focuses on: (i) overcome the simplifications that have been made so far, (ii) try to standardize the decision criteria that must be adopted to define the stability thresholds. (iii) perform measurements on a representative number of vehicles, (iv) develop mathematical modeling of the vehicle-flows interaction, (v) Carry out measurements with vehicles at 1: 1 scale.

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