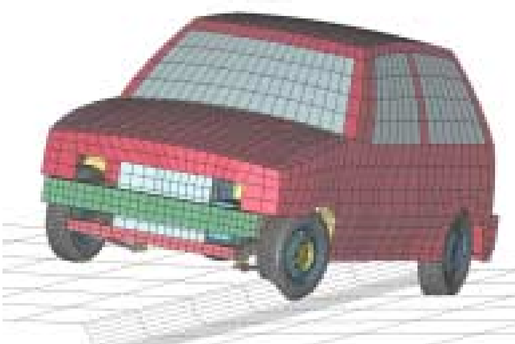
# VEHICLE TRAJECTORIES RESULTING FROM TRAVERSING FDOT STREET CURBS

## PROBLEM STATEMENT

Due to rapid population growth in Florida, highway engineers are addressing more roadside safety issues than they have traditionally faced when designing curbed roadways in urban and suburban areas. Consequently, there is a need for current information on the behavior of errant vehicles traversing curbs. Information currently available is representative of a vehicle fleet that is nearly 30 years old. Up-to-date data and methodologies for predicting vehicle trajectories are needed. However, it is difficult to predict reliably all possible paths of errant vehicles since vehicle trajectories depend on vehicle type, vehicle velocity, angle of approach, weather conditions, curb configuration, condition of tires and suspension, a wide array of possible human reactions, and many other factors. Because of these challenges, comprehensive experimental research would have been prohibitively expensive and limited to only a few vehicles and impact scenarios. Therefore, major efforts were focused on less expensive numerical analyses, which were verified by a few experiments in this study.



## OBJECTIVES

The objective of this project was to determine the trajectories of vehicles after they impact street curbs. This data can help highway engineers design effective roadside barriers on curbed facilities. The Florida DOT types E and F street curbs were selected for this study. A variety of possible roadway-curb configurations and slopes were also considered. In order to obtain reliable predictions regarding real-life situations, various vehicles were considered impacting the curbs at different velocities and approach angles. Two vehicles, the Ford Festiva and the Chevrolet C2500 pickup truck, were of particular interest, since they represent two extremes of the popular vehicle freet ranging from 850 kg to 2000 kg, respectively. The finite element models of both vehicles were used in this study. LS-DYNA nonlinear, 3-D dynamic, explicit finite element code was selected as the primary tool for this analysis. In addition, four full-scale tests were commissioned to provide preliminary validation for computational mechanics analyses for the Ford Festiva and the Ford Taurus.

## FINDINGS AND CONCLUSIONS

This research project may serve as an example of complex real-life problems for which computational mechanics may be used for extensive parametric analyses. This approach allowed for the capturing of kinematic vehicle characteristics significant to roadside safety. Discrete finite element models were implemented in this project in order to study velocities, street profiles, approach angles, friction between tires and road surface, and so forth. Public domain models of the Ford Festiva, the Ford Taurus, and the Chevrolet C2500 pickup truck, developed by the National Crash Analysis Center (NCAC), were used for this study. The original models were developed primarily for frontal impacts and crashworthiness studies. These models were significantly modified to make them more suitable for trajectories studies. Vehicle FE models were simplified by rigidizing most of the body parts, while wheel and suspension models were substantially expanded. New, detailed models of pneumatic tires and detailed models of suspension including spring and shock absorbers were introduced. Parameters for these models were obtained through the laboratory testing of several spring and shock absorbers, which showed a range of possible data, depending on the use of these components. This effort shifted focus from the crashworthiness vehicle characteristics to more detailed suspension models was successful, as later proven by comparisons with data from experiments. It allowed for longer computer runs without "hourglassing" numerical problems and with more reliable results.

Experimental tests, performed for a few selected configurations, served as a final validation of the discrete models and of the computational mechanics methodology. These configurations included a total of four tests with two vehicles (Ford Festiva and Ford Taurus), two approach angles: $15^o$ and $90^o$, and a common velocity of 45 miles per hour. Comparison between data from these four tests and corresponding computational mechanics analysis showed an excellent agreement in acceleration time histories, especially for the smaller Ford Festiva FE model. The validated discrete models of the vehicles allowed for further analytical studies, for cases in which the overall vehicle kinematics played a decisive role. A matrix of a total of 96 different cases was identified and studied in this research. The following characteristics of vehicle trajectories have been examined to validate data from numerical analysis with the corresponding experimental results:

- accelerations of the center of gravity,
- displacements of points located on the vehicle's body (a bumper), and
- overall dynamic behavior of the vehicle body registered during the experiments.

The results obtained from this research indicated that vehicles tend to retain a large amount of their initial kinetic energy after traversing a street curb. Therefore, street curbs should not be considered as roadside safety barriers. Smaller vehicles impacting street curbs at shallow angles also appear to be dangerous, as shown in this study. Although their initial kinetic energy is smaller, they tend to dissipate less energy jumping over the curb with significant amount of residual energy.

## BENEFITS

The behavior of errant vehicles traversing different types of street curbs has been studied for a wide variety of input parameters that include vehicle type, their velocities, and approach angles. This study provides a comprehensive set of information about the trajectory and energy of errant vehicles. Due to the application of two vehicles with extreme values of total weight, dimensions, and characteristics of suspensions, the conclusions are valid for a wide range of vehicles falling between these two categories. The information developed in this study will be useful for determining guidelines for clear zones, needed location of guardrails and ditches, possible tree removals, bus stops relocations, modifications of curb geometry, and so forth. Consequently, the ultimate benefit is increased highway safety.

This project was conducted by Jerry Wekezer, Ph.D., P.E., at the Florida A & M Uniiversity – Florida State University College of Engineering. For more information, contact Tom Bane, Project Manager, at (850) 414-4379, thomas.bane@dot.state.fl.us.