SPEED OF VEHICLES ON GRADES

By

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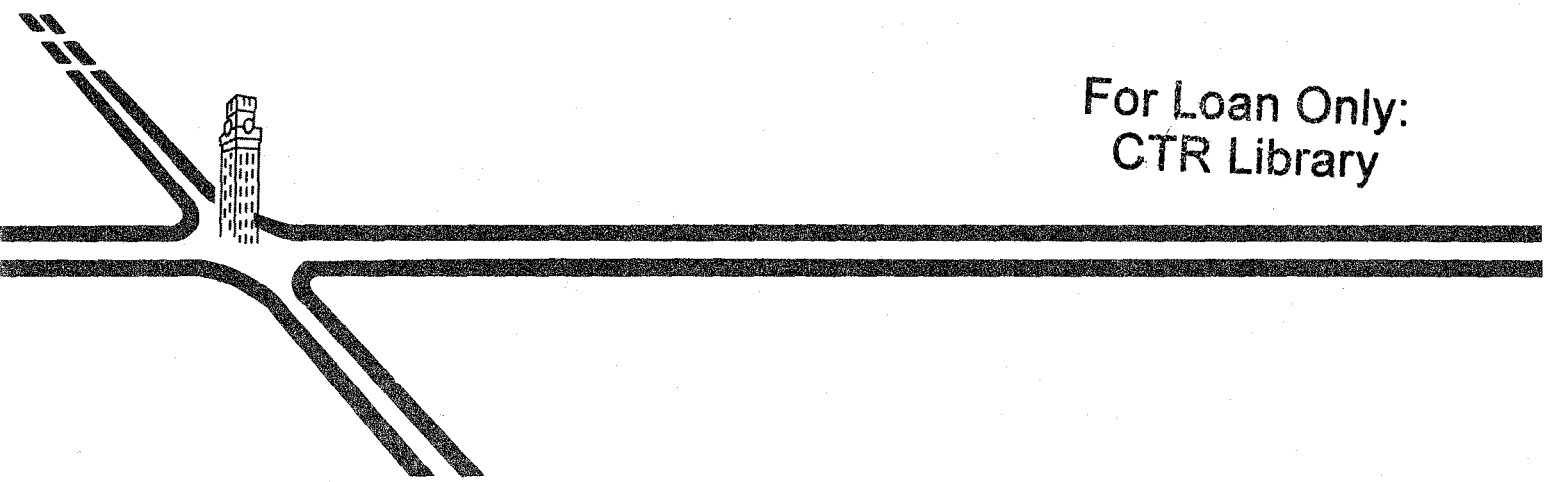


SUMMARY REPORT 20-1F(S)

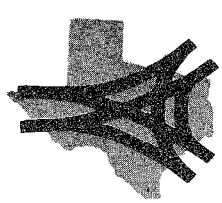
SUMMARY OF

RESEARCH REPORT 20-1F

PROJECT 3-8-73-20

COOPERATIVE HIGHWAY RESEARCH PROGRAM
WITH TEXAS
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
AND
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN
AUGUST 1975



SUMMARY REPORT 20-1F(S)

Foreword

Research Report 20-1F summarizes the findings of Research Project 3-8-73-20, "Speed of Vehicles on Grades," and presents the study procedure leading to the development of new composite speed-distance curves for critical classes of trucks and recreational vehicles operating on a range of vertical grades. A new composite critical length of grade chart employing an approach speed of 55 mph was developed for a range of speed reduction values.

Introduction

The objective of this study was to obtain new field data concerning motor vehicle operating characteristics on selected grades and to relate these data to current and future geometric design standards for highway grades, with particular emphasis on the capacity and safety aspects of vehicle climbing lanes. To attain this objective, the research project was subdivided into five phases encompassing a two-year time frame:

Phase 1. Collection, review, and compilation of literature relating to the operating characteristics of motor vehicles on vertical curves.

Phase 2. Collection of data at selected field sites. This phase involved the design of a field data collection experiment, development of data collection techniques, and the selection of data collection sites.

Phase 3. Analysis of Data. The data generated and compiled from the field observations were analyzed and tabulated for comparison with current climbing lane design criteria. In addition to truck operating performance on grades, special attention was also given to recreational vehicles.

Phase 4. Methodology Recommendations. From the analysis of data in the previous phase, a series of design charts was developed on the basis of vehicle classification, weight/horsepower ratios, approach speeds, speed reduction, percent grade, and length of grade. This series of figures provides the highway designer with the flexibility of evaluating design criteria on existing highways with more analysis tools than previously available.

Phase 5. Conclusions and Recommendations. The findings and recommendations cited herein provide revised climbing lane design criteria based on the analysis of actual field data of the operating performance of trucks and recreational vehicles on selected representative grades within the State of Texas.

Conclusions and Recommendations

Conclusions

An extensive state of the art review of the performance characteristics of trucks and recreational vehicles on highway vertical curves indicated the need for verifying the effectiveness of current climbing lane design standards. Because of the complexity of obtaining actual field data on various types of these vehicles as classes, there had not been any extensive field studies for over twenty years. Even the work performed at that time involved that which may not reflect actual operating characteristics and conditions.

Speed and weight data for trucks operating on existing highway grades were collected in field studies at four sites located in central and east Texas. The data on recreational vehicles were obtained at three sites on major recreational routes in central Texas. Two different data collection techniques were employed: photo sensitive devices and car-following. The weigh-in-motion system was used on one site near central Texas and at the east Texas locations. A questionnaire was also employed to survey the owner of the vehicles on vehicle attributes and driver characteristics. An approximate 40 percent return of the questionnaire enabled the researchers to test the significance of driver experience in relation to vehicular performance.

From the speed history records, speed-distance curves were developed using a stepwise multiple regression analytical technique. As many as 12 selected roadway, vehicle, and driver variables were used in an attempt to explain the observed speed variation of each class of truck, truck combination, and recreational vehicles (classification of which was developed by the researchers in this study).

Two classes of trucks with particular characteristics were found to experience greater speed losses than others: 3-S2 semi-trailer combinations and log trucks with typical weight/horsepower ratios of 370 and 385 respectively. These vehicles were used as the critical vehicular types in developing truck climbing-design charts. Concerning the recreational vehicles, the most critical category was found to be the vehicle pulling travel trailers. This category currently enjoys the largest share of the recreational market and is considered to be representative of the operating characteristics for all recreational vehicles.

In both classes of vehicles approach speed was found to have a significant effect on the vehicle operating characteristics on grades. A set of speed ranges was devised for critical lengths of grade analysis.

Composite design charts (Figs 1, 2, 3, and 4) were developed with an approach speed of 55 mph, a range of speed reduction values in mph, percent grades, and length of grade. By direct comparison with the currently accepted design charts, one can observe that in some instances there is a significant difference in the resultant length of climbing lane required for a given speed reduction constraint. It can be observed that for specific grades the new composite design charts using a speed reduction limit of 10 mph yield similar length of grade figures obtained by using current AASHTO and SDHPT design charts with a 15 mph speed reduction limit. The new design values yield performance characteristics which are more indicative of the actual vehicular behavior than previous data and design charts. It is observed that recreational vehicles are not as critical as trucks in the design of climbing lanes. However, it is suggested that on certain routes such as designated recreational routes with a low percentage of trucks and

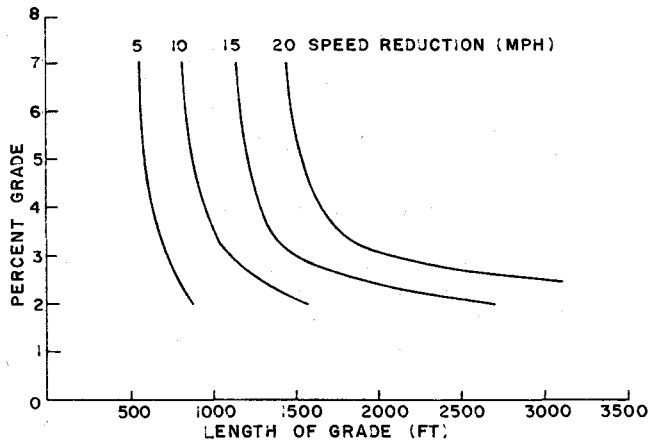


Fig 1. Critical lengths of grade using an approach speed of 55 mph for a composite truck weight/horsepower ratio.

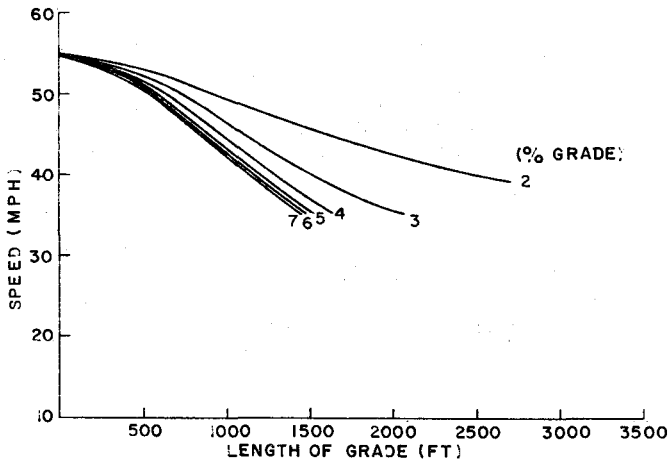


Fig 2. Composite speed-distance curves for a typical heavy truck on selected upgrades.

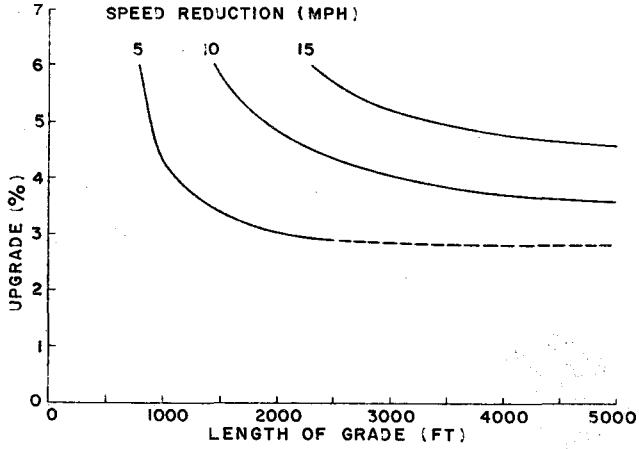


Fig 3. Critical lengths of grade using an approach speed of 55 mph (assumed typical recreational vehicle).

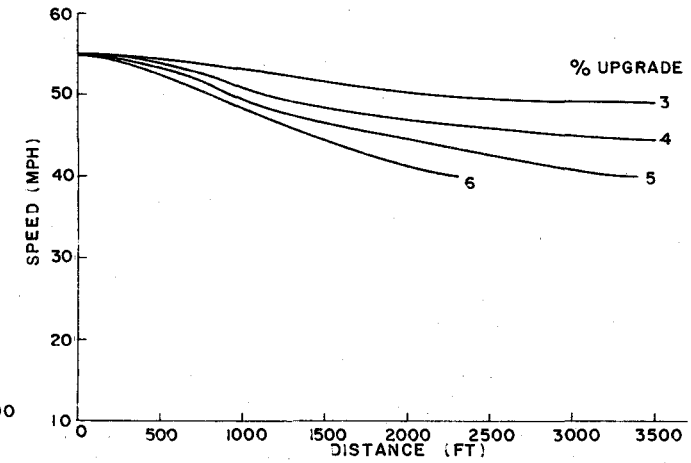


Fig 4. Speed-distance curves for a typical recreational vehicle on selected upgrades.

where a truck climbing lane may not be warranted, that sufficient recreational vehicular traffic may indicate a demand for an additional lane which can be evaluated utilizing the design charts developed herein.

Recommendations

Based on the findings of this research, the following recommendations can be made:

(1) the composite critical length of grade and speed-distance curves charts (Figs 1, 2, 3, and 4) should be considered for application in the evaluation of the need for and the design of climbing lanes for trucks and recreational vehicles respectively, and

(2) the utilization of an approach speed of 55 mph for the evaluation and design of climbing lanes is recommended.

Further evaluation and study is recommended in the following areas:

(1) 10 mph vs. 15 mph speed reduction criteria. There are strong cases for both. The safety aspects associated with the 10 mph speed reduction suggestion is balanced against the resultant requirement to reevaluate existing climbing lanes, design, and construction of additional facilities and the current austerity program and priorities for other facilities within the state. At this time, this appears to be more of a policy decision than a design procedure. It is suggested that a program of continuing the 15 mph reduction, while not an ultimate or ideally the "best" case, is at least a compromise providing better safety to the traveling public than previously provided;

(2) reevaluation of current warrants for climbing lanes in view of the findings of this study;

(3) further study of the performance of vehicles on downgrades. In relation to recreational vehicles, an acceleration of 1 mph per 300 feet of 0.5 percent downgrade was observed in this study. Additional information would be required to evaluate the requirements for terminating a climbing lane;

(4) further analysis of vehicle equivalencies to facilitate capacity and level of service analysis. Questions remain concerning the effect of various vehicles on capacity. Current studies being conducted elsewhere may provide additional guidance in this area;

(5) roadway signing and marking of climbing lanes; and
(6) effect of driver behavior and experience on vehicle performance. From our limited sample relating to the driver, this factor proved to be significant in contributing to the other explanations of the vehicle performance on grades.

Implementation Guidelines

The efficiency and reliability of geometric design criteria, capacity analysis, and safe operation are of paramount importance to every highway engineer. It is necessary to verify these criteria periodically since road user behavior and vehicle operating characteristics are continually changing.

It was the purpose of the study to investigate the speed characteristics of various classes of motor vehicles operating on selected highway grades. The findings are reflected in an evaluation of current theory and design practice, and recommendations for alteration of standards are made.

The study included an evaluation of the operating characteristics of trucks and classes of vehicles such as car-trailer combinations not previously considered, and a resulting methodology for evaluation of the impact of these vehicles on design, capacity, and safety as related to speed characteristics on grades was developed. These findings and recommendations were coordinated with the State Department of Highways and Public Transportation design and traffic safety personnel to expedite implementation into departmental practice as warranted. The same information will be of interest to the Federal Highway Administration, which in turn might lead to changes in AASHTO's present design criteria for climbing lanes.

The findings from this research effort have been incorporated in the preliminary revision of Part IV of the Highway Design Manual by personnel in D-8 design. Geometric design standards concerning vehicle operating characteristics on grades have been evaluated on the basis of actual field data. The benefits to be accrued include:

(1) more efficient and economical design procedures for climbing lanes, freeway ramps, and other highway grades based on vehicle operating characteristics;
(2) increased capacity of the highway systems;
(3) increased safety, convenience, and savings to the highway user; and
(4) data gathered during this project provided vehicle operating characteristics of different classes of motor vehicles and vehicle combinations and will lead to improved techniques for evaluating existing designs and making capacity analyses.

KEY WORDS: climbing lanes, vehicle characteristics, trucks, recreational vehicles, vehicle speed-distance curves, weigh-in-motion, car-following.

The full text of Research Report 20-1F can be obtained from Mr. Phillip L. Wilson, State Planning Engineer, Transportation Planning Division, File D-10R, State Department of Highways and Public Transportation, P.O. Box 5051, Austin, Texas 78763.