



Standard Practices for Simulating Truck Response to Longitudinal Profiles of Vehicular Traveled Surfaces¹

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1. Scope

1.1 These practices cover the calculation of truck response to longitudinal profiles of traveled surface roughness.

1.2 These practices utilize computer stimulations to obtain two truck responses including: sprung and unsprung mass vertical displacement, velocity and acceleration, and sprung mass pitch angular displacement, velocity and acceleration.

1.3 These practices present standard truck simulations (quarter truck, half-single unit truck, and half-tractor semi-trailer) for use in the calculations.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

E867 Terminology Relating to Vehicle-Pavement Systems

E950 Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference

2.2 *ISO Standard:*³

2631 Guide for the Evaluation of Human Exposure to Whole-Body Vibration

3. Terminology

3.1 See Terminology E867.

¹ These practices are under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and are the direct responsibility of Subcommittee E17.33 on Methodology for Analyzing Pavement Roughness.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

4. Summary of Practice

4.1 These practices use a measured profile (see Test Method E950) or a synthesized profile as a part of a computer simulation to obtain truck response.

4.2 The first practice uses a standard truck simulation to obtain truck sprung mass vertical acceleration. The acceleration history can be computed as a function of time or distance. One application of this practice is to use the acceleration history in ride quality evaluation, such as the ISO Guide 2631. Another application is to use the sprung mass vertical displacement history as input to a suspended seat model in ride quality evaluation.

4.3 The second practice uses a truck simulation model to obtain tire/pavement vertical forces as a function of time or distance. One application of this practice is to use the tire/pavement history in pavement loading evaluation.⁴

4.4 For all calculations, a truck speed is selected and maintained throughout the calculation. Pertinent information affecting the results must be noted.

5. Significance and Use

5.1 These practices provide a means for evaluating truck ride quality and pavement loading exerted by truck tires.

6. Apparatus

6.1 *Computer*—The computer is used to calculate truck response to a traveled surface profile using a synthesized profile or a profile obtained in accordance with Test Method E950 as the input. It is recommended that a 16 or more-bit digital computer be used.

6.2 *Data-Storage Device*—A data storage device shall be provided for the reading of profiles and the recording and long-term storage of computed data. Profile data shall be scaled to maintain resolution of 0.025 mm (0.001 in.) and to accommodate the full range of amplitudes encountered during normal

⁴ Todd, K.B., and Kulakowski, B.T., "Simple Computer Models for Predicting Ride Quality and Pavement Loading for Heavy Trucks," *Transportation Research Record* 1215, 1989, pp. 137–150.

TABLE 1 Quarter-Truck Model Parameters

Symbol	Single Unit Truck Front Axle	Single Unit Truck Rear Axle
M_s	2447.5 kg (14.0 lb•s ² /in.)	4003.5 kg (22.9036 lb•s ² /in.)
M_u	279.7 kg (1.6 lb•s ² /in.)	524.5 kg (3.0 lb•s ² /in.)
K	198251.1 N/m (1132. lb/in.)	1138367.4 N/m (6500. lb/in.)
C	2627.0 Ns/m (15. lb•s/in.)	2627.0 Ns/m (15. lb•s/in.)
K_t	788100.5 N/m (4500. lb/in.)	875667.3 N/m (5000. lb/in.)

TABLE 2 Half-Single Unit Truck Model Parameters

Symbol	Description	Numerical Value
M_s	One half vehicle sprung mass	6451.0 kg (36.9 lb•s ² /in.)
I_y	One half sprung mass pitch moment	46249.0 Nms ² (410876.4 lb•s ² /in.)
M_{u1}	One half front axle unsprung mass	279.7kg (1.6 lb•s ² /in.)
M_{u2}	One half rear axle unsprung mass	524.5kg (3.0 lb•s ² /in.)
K_1	Front suspension spring constant	198251.1 N/m (1132. lb/in.)
K_2	Rear suspension spring constant	1138367.4 N/m (6500. lb/in.)
C_1	Front suspension damping constant	2627.0 Ns/m (15. lb•s/in.)
C_2	Rear suspension damping constant	2627.0 Ns/m (15. lb•s/in.)
K_{t1}	Front tire spring constant	788100.5 N/m (4500. lb/in.)
K_{t2}	Rear tire spring constant	875667.3 N/m (5000. lb/in.)
A	Horizontal distance from front axle to sprung mass center of gravity	3.79 m (149.2 in.)
B	Horizontal distance from rear axle to sprung mass center of gravity	2.31 m (90.9 in.)

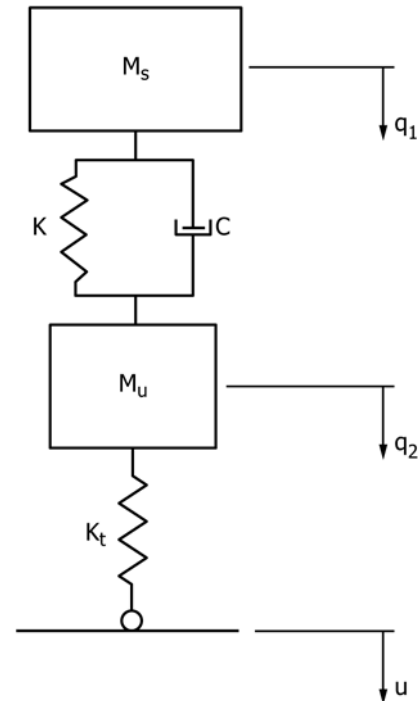


FIG. 1 Quarter-Truck Model

profile-measuring operations. The devices shall not contribute to the recorded data any noise amplitude larger than 0.025 mm (0.001 in.)

6.3 *Simulation Input*—Digital profile recordings of road-roughness profiles shall be obtained in accordance with Test Method E950 or synthesized. The profile must be recorded at intervals no greater than one third of the wavelength required for accurate representation of the traveled surface for the intended use of the data. For most applications, a sample interval of 0.15 m (0.5 ft) will give a valid representation for all types of road surfaces. When more than one path of a traveled surface is measured, the recorded profile data for the paths shall be at the same longitudinal location along the measured profiles to avoid phase shift between the paths. The recorded profile shall include all of the noted field data described in the Procedure (Data Acquisition) and Report sections of Test Method E950. The length of the road-roughness profile must be reported with the results; however, caution must be exercised to ensure that transients in the simulation do not influence the results. It is recommended that at least 160 m (0.1 miles) of profile, preceding the test section, plus the desired test section be used as input in simulation to eliminate the effects of transients.

7. Truck Simulation Programs

7.1 These practices use one of the three truck simulation models described in Footnote 4: a quarter truck, a half-single unit truck, and a half-tractor semitrailer. To develop the mathematical models, the following was assumed:

- 7.1.1 Constant truck velocity,
- 7.1.2 No body or axle roll,
- 7.1.3 Rigid truck bodies,
- 7.1.4 Linear suspension and tire characteristics,
- 7.1.5 Point tire to road contact, and

7.1.6 Small truck pitch angles.

7.1.7 Although several methods for numerical solution of differential equations are available, the fourth-order Runge-Kutta method is employed in Footnote 4. The parametric models, shown in Fig. 1, Fig. 2, and Fig. 3, constitute the standard practice. The analytic representations of the models and the methods of implementation need not be the same as outlined in Appendix X1.

7.2 *Quarter Truck Simulation Model*—The quarter truck model is shown in Fig. 1, with q_1 as the truck-body (sprung mass) displacement, q_2 as the tire (unsprung mass) displacement, and u as the road profile. The state variable equations of motion are given in X1.1. Two sets of model parameters, one for front axle and the other for rear axle, are given in Table 1. Front axle parameters should be used in ride comfort studies and rear axle parameters in pavement loading

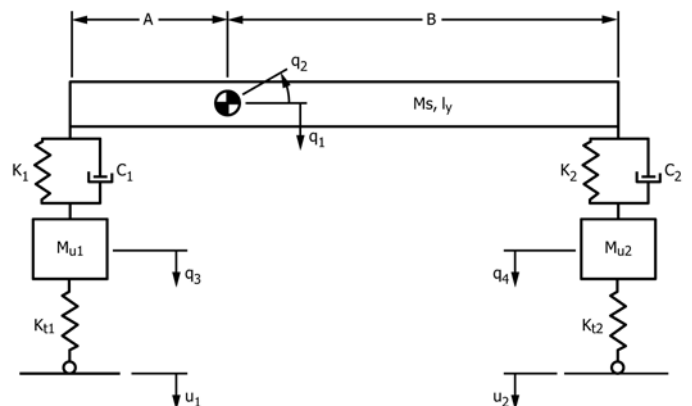


FIG. 2 Half-Single Unit Truck Model