TechBrief

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Development, Evaluation, and Application of Performance-Based Brake Testing Technologies

The vision of the Office of Motor Carriers is to help move people, goods, and commercial motor vehicles on our Nation's highways in the most efficient, economical, and crash-free manner possible. The OMC research and technology program focuses on improving safety in interstate commercial motor vehicle operations and serves a trucking and motor coach industry that carries more than 40 percent of all intercity freight.

Studies are conducted in the following areas: commercial driver human factors, health, and performance needs; new and emerging driver and vehicle technologies; safety-related data collection and analysis needs; and performance-based changes to the Federal Motor Carrier Safety Regulations.

The OMC's technology research promotes safety by identifying, collecting, and communicating information about technological advances.

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Introduction

A performance-based brake tester (PBBT) is a device that can assess the braking capability of a vehicle through a quantitative measure of both individual brake and overall vehicle performance in a controlled test. The primary benefit of PBBTs to both the enforcement and the motor carrier communities is that they provide an objective, consistent, and standard measure of the as-is braking performance of a vehicle. PBBTs can be used to assess braking capability irrespective of brake type (disk or drum), energy supply (air, hydraulic, electric, or spring), or application method (s-cam, wedge, piston, spring, or lever and cable). This Tech Brief presents a summary to date of a Federal Highway Administration-sponsored project that is fully documented in a separate report.

Purpose

The inspection procedure and pass-fail criteria for braking systems on commercial motor vehicles in North America are provided by the Commercial Vehicle Safety Alliance (CVSA). The inspection procedure and criteria are used by federal, state, and provincial agencies in the United States, Mexico, and Canada for commercial motor vehicle inspection and enforcement. The procedure requires an inspector to get underneath a vehicle in order to check visual, aural, and tactile indicators of potential brake performance. These sensory inspections can be subjective, time consuming, labor intensive, and difficult.

PBBT evaluations are intended to be an alternative method for brake evaluation based upon actual brake performance, rather than visual inspection, and can be conducted without crawling underneath the vehicle. PBBTs can do an excellent job of rapidly identifying weak brakes or unsafe vehicles, but will not replace the current CVSA procedure for inspecting brakes and their components. Because the two techniques measure different factors, inspectors can use both performance-based and visual evaluations to assess and maintain brake performance.

The purpose of this study was to determine, through field test data collection and additional analytical and experimental studies, if PBBTs could improve commercial motor vehicle safety and assist with timely throughput at inspection sites, while improving the accuracy of currently employed sensory brake inspection techniques.

Two specific goals were to:

- Develop performance-based criteria for identifying weak or defective brakes.
- Determine if any limitations exist that might prevent the future use of PBBTs for assessing brake performance.

Research Methodology

Researchers evaluated several first and second generation prototype PBBTs. CVSA certified inspectors tested roller dynamometers, flat plate testers, and breakaway torque testers for at least 1 year in the field. Two additional brake assessment methods, infrared brake drum temperature measurement and an on-board decelerometer, were also investigated, though less extensively. Ten states participated in the program, each assessing a particular PBBT.

During the field testing, inspectors evaluated the brake performance of almost 3,000 commercial vehicles. These joint inspections consisted of a CVSA Level 4 inspection (comprised of the driver, brake, and tire portion of a Level 1 full inspection) and a PBBT test. Both inspections were conducted to compare brake defect rates between visual inspection and performance-based brake test techniques.

Findings

Information available from the various PBBTs includes: brake force, brake force versus air pressure, axle or individual wheel weight, dynamic axle or wheel weight, parking brake force, threshold brake application pressure, and brake timing. In addition to correlations derived from the results of joint CVSA brake inspections and performance-based machine tests, researchers collected data pertaining to machine utility, such as vehicle throughput, machine maintenance requirements, inspector skill level requirements, and cost benefit analyses. This study predicts inspectors can screen at least 30, and as many as 80, 5-axle vehicles per 8-hour day for CVSA inspection using one of the PBBT technologies.

Flat plate brake tester

Performance-Based Criteria

Based on analysis of the field test data, recommended PBBT criteria for identifying weak brakes are measured in terms of forces and weights, such as:

- A minimum force at a given air pressure for pneumatically braked vehicles, using recommendations previously developed by the National Highway Traffic Safety Administration's Vehicle Research Test Center.
- A minimum ratio of brake force balance across an axle of 0.65 or better for any vehicle or brake type.
- A minimum brake force (BF) as a function of wheel load (WL) for any vehicle or brake type. A minimum BF/WL ratio of 0.25 is recommended for steer axle brakes. A minimum 0.35 ratio is recommended for non-steer axle brakes.

This study also examined recommendations for vehicle out-of-service (OOS) criteria. Inspectors would place a vehicle OOS if its braking capability falls below a certain threshold and it is an imminent hazard. Two approaches are proposed:

- A vehicle may be placed OOS if 20 percent or more of its brakes are found to be defective using one of the above PBBT criteria.
- A vehicle may be placed OOS if it cannot meet a minimum equivalent deceleration criterion (e.g., if the deceleration is < 0.4g, where g is the acceleration due to gravity [9.8 m/sec2 or 32.2 ft/sec2]). The equivalent deceleration can be computed from brake force and weight measurements obtained with a PBBT. Additionally, a stopping distance can be predicted (e.g., 12.2 meters from 32.2 km/hr [40 feet from 20 mph] or 105.2 meters from 97 km/hr [345 feet from 60 mph]) from this equivalent deceleration.

A third type of vehicle OOS criterion based on the results of a PBBT considers the brake force and load distributions. This adds the consideration of braking stability to minimum stopping distance. Braking

Roller dynamometer

stability refers to the ability of a vehicle to maintain stable travel in its lane during a stop. The data required for development of these criteria were not available from the field testing, but future work is planned.

The overall agreement for individual weak or defective brakes identified by CVSA inspection and those identified using a PBBT range from 52 to 88 percent, depending upon the particular state and the type of PBBT used. These levels of agreement are reasonable considering that the different techniques assess different factors.

The study found that many of the vehicles placed OOS using CVSA criteria had sufficient stopping capability when their brakes were evaluated in terms of the proposed PBBT criteria. Of 2,865 trucks inspected using both methods, inspectors placed 396 OOS under the CVSA standards. Out of these 396, only 215 would have been placed OOS due to the failure of 20 percent or more of their brakes in a PBBT. Only 179 had an insufficient predicted overall vehicle deceleration (< 0.4g), as measured by a PBBT. This means that approximately 50 percent of the vehicles placed OOS by the CVSA criteria had adequate braking capability as judged by PBBTs.

However, the total number of vehicles that would have been placed OOS using the proposed PBBT criteria was considerably larger. Of the same 2,865 vehicles, 559 would be placed OOS using the PBBT 20 percent criteria, and 1,124 vehicles would be placed OOS using the minimum 0.4g deceleration criteria.

While there is some concern that PBBT results may be overly conservative with good brakes, PBBT identification of weak brakes and vehicles with inadequate stopping capability was clearly demonstrated.

Since the CVSA visual inspection is qualitative and subjective, and the PBBT assessment is quantitative and objective, the degree of agreement between the two techniques was found to be of minimum significance. The research suggests that both techniques could be used simultaneously to help drivers, inspectors, and maintenance personnel maintain and operate a safer vehicle.

Limitations of PBBTs

No insurmountable performance or operational limitations exist specifically for roller dynamometers, flat plate testers, or breakaway torque testers that would prevent these technologies from being used in the future for screening or enforcement.

Researchers did find that the applicability of the infrared temperature measurement system was limited to the detection of inoperative brakes or brakes with stroke measurements greater than 12.7 mm (0.5 inch) beyond the recommended adjustment limit. This was due to the wide range of temperatures found on brakes that appeared to be in proper working order. The on-board decelerometer, while valid for screening or enforcement, showed limited applicability because of the logistics of test "runway" space limitations, strong dependance on driver skills, and potential damage to deceleration-sensitive cargo. Further investigation of these techniques is likely.

Several limitations exist for performance-based technologies as a whole. PBBTs cannot replace the inspector for finding a number of defects, such as chafed hoses and thin brake pads, that do not directly affect brake force. In addition, none of the PBBT technologies currently can predict braking capabilities for vehicles with overheated brakes based on tests performed on cold brakes.

Another concern is that certain low-ground clearance vehicle configurations could not be tested on portable PBBT units without the use of special ramps or platforms. Research found portable units to have a

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Distribution
This Tech Brief is being distributed according to a standard distribution. Direct distribution is being made to the Resource Centers and Divisions.

Availability
The draft final report is under review and will be available upon completion.

Key Words
brake, performance-based brake tester, commercial motor vehicle, brake performance, commercial motor vehicle safety, brake inspection, defective brake, brake force.

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higher initial cost and higher expected maintenance costs, along with a lower expected reliability than the same units mounted in-ground.

Future Uses

Through this study, a plan has been developed for using PBBTs for enforcement and for incorporation with Intelligent Transportation Systems technology. In the future, a vehicle will be automatically identified as it approaches a roadside or fixed-site inspection facility. An identifier will be transmitted electronically to a computer network (Commercial Vehicle Information Systems and Networks [CVISN]) for access to credentials and safety information that would be carrier, vehicle, and potentially driver specific. Once downloaded, this information could be utilized to make informed decisions at inspection sites on the selection priority of carriers, vehicles, and drivers.

If directed into the inspection facility, vehicles would undergo a PBBT test (including brake forces, wheel loads, and axle spacings), to be completed in just a few minutes. Safe stopping capability and in-lane braking stability would also be calculated. The test results would be automatically transmitted to the roadside inspector's computer and written into the vehicle inspection software. If the vehicle fails the minimum deceleration or stability standard, it would immediately be placed OOS. If passed, it would be directed back into mainline traffic. In both cases, the information obtained from the PBBT would be recorded and uploaded to a vehicle transponder, an on-board computer system, and/or an electronic data mailbox. The inspection record would also be uploaded to various components of the CVISN and stored, contributing to a historical performance record of the carrier and vehicle. It may also be used to provide an advanced safety screening of the vehicle.

Additionally, the results of the PBBT would provide performance data to allow the vehicle's on-board computer to calculate a safe following distance for the current conditions. The results would inform a driver of predicted braking capability or instability problems that might arise from changes in loading conditions, or tire/road frictional problems arising from changing weather or road conditions. The driver would receive information indicating the current following distance and the safe following distance, and a warning system would alert the driver if safe following distance was compromised or violated.

PBBT technology can be used as both an enforcement tool and a diagnostic aid for maintenance and repair. While PBBTs will not replace the CVSA visual inspection process, they will provide maintenance and inspection personnel with an additional tool for assessing the braking capability of a vehicle.