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Analysis of developed transition road safety barrier systems

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ABSTRACT

Road safety barriers protect vehicles from roadside hazards by redirecting errant vehicles in a safe manner as well as providing high levels of safety during and after impact. This paper focused on transition safety barrier systems which were located at the point of attachment between a bridge and roadside barriers. The aim of this study was to provide an overview of the behavior of transition systems located at upstream bridge rail with different designs and performance levels. Design factors such as occupant risk and vehicle trajectory for different systems were collected and compared. To achieve this aim a comprehensive database was developed using previous studies. The comparison showed that Test 3–21, which is conducted by impacting a pickup truck with speed of 100 km/h and angle of 25° to transition system, was the most severe test. Occupant impact velocity and ridedown acceleration for heavy vehicles were lower than the amounts for passenger cars and pickup trucks, and in most cases higher occupant lateral impact ridedown acceleration was observed on vehicles subjected to higher levels of damage. The best transition system was selected to give optimum performance which reduced occupant risk factors using the similar crashes in accordance with Test 3–21.

1. Introduction

Growth in the automotive industry has had a positive effect on economic development. In spite of the advantages of improving human life, motorization has some disadvantages including road crashes. Accidents are a serious problem on highways and will increase with increasing rates of car ownership and the speed of vehicles on roads (Olegas et al., 2009; Hiselius, 2004; Elvik, 1995a; Partheeban et al., 2008; Fred et al., 2008).

Two aspects are essential in terms of traffic safety. The first aspect is accident prevention and the second is the minimization of accident severity once a crash has occurred (Denis, 1997). More severe crashes are those where vehicles cross the meridian and crash into other objects (Olegas et al., 2009). Recent research has showed that crashes with solid objects located beside highways, such as poles and trees, cause many fatal injuries (Holdridge et al., 2005; Wang et al., 2011). Consequently, there is a need to consider effective road restraint systems to increase safety (Ren and Vesenjak, 2005; Bruce et al., 2010).

One type of road restraint system is a roadside barrier. The purpose of roadside barriers is to redirect errant vehicles back to the roadway after impact (Brian et al., 2006). These barriers are installed in two directions. First, the barriers are installed along the roadside to prevent vehicles from traversing a steep slope and impacting roadside objects, and second, median barriers are installed to prevent vehicles from entering opposite lanes (Gabauer et al., 2010; Gabauer and Gabler, 2009; Borovinsek et al., 2007).

Guardrails are the most common safety barrier used along roadsides to reduce the consequences of accidents (Elvik, 1995b). Previous studies have demonstrated that a well-designed guardrail system can effectively contain and redirect vehicles after an impact and minimize the effects of a crash on a vehicle and its occupants. These kinds of barriers are commonly flexible to minimize damage to the vehicle (Ali et al., 2008).

Another common barrier application is to shield vehicles crossing a bridge path from possible dangers (Karla et al., 2007). Bridge rails must be rigid to prevent extensive barrier deflection owing to the lack of space on bridge structures. The most common bridge rails are concrete walls or stiffened metal rails.

Special attention should be given to the end treatment of a bridge rail to reduce the severity of a crash. Based on a study conducted by the Minnesota Department of Transportation, it was concluded that the possibility of serious injury and fatality could be considerably decreased (from 28.5% to 6%) by using the bridge approach-guardrails for bridges (Tim et al., 2005).

In this case, due to the flexibility of roadway barriers and rigidity of bridge barriers, severe vehicle pocketing and wheel snagging occur at the point of attachment. To eliminate these problems, a

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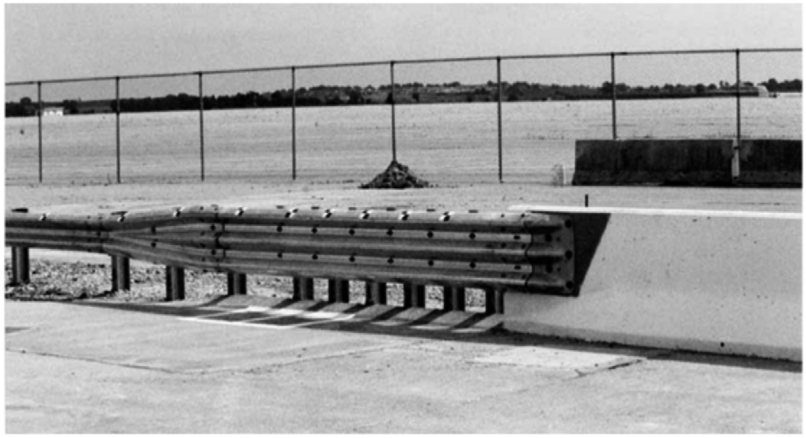

Fig. 1. Transition system.

semi-rigid transition system is commonly used between these two structures. The main purpose of this transition system is to position a structure to gradually change in stiffness from the roadway barrier to the bridge barrier. Fig. 1 illustrates this type of transition system (Ronald et al., 1998).

2. Objectives

Design considerations for transition systems include safety, economics, structural integrity, ease of construction and maintenance (Ronald et al., 1998). Different full scale crash tests were used to assess the performance of various transition systems. In order to address important points regarding current transition systems and the effects to a vehicle and its occupants during a crash, it was necessary to develop a guideline based on former studies and a comparative methodical foundation. In this case, attention was given to the combination of parameters associated with different conditions and criteria. Hence, the purposes of this study were as follows:

(1) To provide data collected from test results as well as an overview of the performance of previously tested transition systems during and after impact.
(2) To evaluate transition deflection as an important parameter for transition systems associated with different designs and test levels.
(3) To compare the results of different design methods subjected to different test levels to assess less severe crashes in terms of occupant risks factors and vehicle trajectory.
(4) To compare the impact velocity of the occupants and subsequent ridedown acceleration using a Flail Space Model (FSM) from several crash tests subjected to different types of vehicle damage to find a correlation between these factors.
(5) To find the best design for transition systems to minimize the severity of the injuries experienced by the occupants of a vehicle.

3. Methods

There are limited studies that evaluate the performance of transition systems due to the considerable cost of performing full scale crash tests. As a result, predicting the behavior of this component and discovering relationship between factors would help designers and engineers reduce construction costs and the number of tests. The specific methodology used in this study included a collection of real crash test results for transition systems. This study went on to conduct an analysis involving main factors affecting the behavior of transition systems. To achieve these objectives this study was divided into four phases described in the following section.

The parameters that can affect the performance of a transition system must to be defined. In this study, these indicators were based on three main requirements (test condition, safety evaluation criteria and transition design) to assess the performance of a transition system. In the second phase, a comprehensive database was created from 30 crash tests performed to assess transition systems. In the third phase, the crash tests data was sorted into different test levels. In the fourth phase of the study, various combinations of indicators were analyzed and categorized in terms of the effectiveness of different parameters on the crash behavior of the system.

4. Current criteria for evaluating transition systems

The performance of safety barriers were evaluated by the National Cooperative Highway Research Program (NCHRP) and the American Association of State Highway and Transportation Officials (AASHTO) using either the NCHRP report 230, NCHRP Report 350 and recently released Manual for Assessing Safety Hardware (MASH) by AASHTO (Ferdous et al., 2011). In the last few years, several tests were performed to assess the performance of safety roadside barriers. These tests reported that most of the designs were accepted for highway use according to the criteria set out in the NCHRP Report 230 (Ronald et al., 1998).

In July 1993, the NCHRP Report 350 added additional aspects and tests to assess the performance of roadside barriers. Test procedures for Report 230 were changed in the NCHRP Report 350. The most significant change was the change of 4500-lb to the 2000p for test conditions (King and Roger, 2002). In 2009 a new criteria, called MASH, was revealed by AASHTO to assess the performance of roadside barriers. MASH used the same procedures used in the NCHRP Report 350 to assess the performance of hardware features, which were verified in terms of speed, angle of impact and the weight of vehicles.

4.1. Test method requirements

In general, there are six different tests levels used to evaluate the performance of transition systems. The lower tests levels are used to evaluate the safety barriers on low traffic roadways. The higher test levels are used to evaluate hardware features on high traffic roadway areas. Test level 1 (TL-1) was designated to qualify features inside work zones or lower service level roadways.