Development of Strength Performance and Practical Structure Required for Bollards to be Installed on Sidewalks at Intersections

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1. Introduction

A "bollard" (also known as buffer stop) is a type of guard fence that is defined as a "fence or guard fence on the road" installed as an "accessory of the road" in Item 1, Paragraph 2, Article 2 of the Road Act. Bollards are used for various purposes as they are installed to prevent vehicles from entering, parking, or crashing into road facilities. Furthermore, bollards can be an alternative to protective fences in areas where the continuous installation of guardrails or other protective fences is difficult or inappropriate. However, impact-resistant bollards that can resist vehicle collisions, like guardrails, have not been widely used in Japan.

In response to the growing need for measures to protect pedestrians, etc. waiting on sidewalks at intersections, NILIM and the Road Bureau of MLIT have studied the concept of using bollards at crosswalk connections and intersection corners ("crosswalk connections, etc."), listened to the opinions of academic experts and compiled the results. The results were published as the "Handbook for Bollard Installation" (the "Handbook") by the Japan Road Association (March 2021), which has been widely disseminated to road administrators, etc.

This paper presents an overview of the study on the setting, evaluation method, etc. for the strength performance required for impact-resistant bollards based on the analysis of traffic accident data, traffic accident simulations, and collision tests using actual vehicles.

2. Definition of bollard

Photo 1 shows an example of bollard installation at a crosswalk connection. These bollards are intended to deter vehicle entry by visually emphasizing the distinction between the crosswalk connection and other areas but do not stand up to vehicle collisions, etc. They are defined in the Handbook as an "N-type bollard". On the other hand, the Handbook defines an H-type bollard as an impact-resistant bollard that resists vehicle collisions and prevents vehicle entry, in addition to distinguishing the crosswalk connection, etc.

Photo 1: Example of bollard installation (N-type bollard)

3. Study on the setting of strength performance

The types of impact-resistant H-bollards shown in the **table** below are set according to the design speed of the roads where bollards are installed. The **table** shows the collision conditions to verify the strength performance. Collision tests with an actual vehicle are necessary to verify that H-type bollards have enough strength to prevent vehicles from significantly entering the sidewalk by stopping the vehicle or pushing it back.

Table: Setting according to types (collision conditions)

Type	Vehicle mass (t)	Collision speed (km/h)	Entry angle (Angle at entry into the sidewalk) (°)
H_C	1.8	35 or more	15
H_B	1.8	45 or more	15

* Hc "applies to roads with a design speed of 50 km/h or less, and "H_B" applies to roads with a design speed of 60 km/h.

Collision conditions were set based on the behavior of a straight-through vehicle that collided with a right-turning vehicle, after taking into account the tendency of collisions between right-turning and straight-through vehicles that occur at standard signalized intersections (see **Fig.**).

To be the safe (large mass) side, the vehicle mass was

set to 1.8 tons based on an analysis of traffic accident data, which confirmed that vehicles entering crosswalk connections, etc. (straight-through vehicles that collided with right-turning vehicles) are mainly passenger cars, and by organizing the number of passenger cars owned according to the mass of those cars.

The collision speed was set using traffic accident simulation software. Assuming the traffic accident shown in the **Figure**, we reproduced a situation where the speed of a straight-through vehicle decreased due to a collision with a right-turning vehicle and the straight-through vehicle entered the sidewalk. In reproducing the situation, the speed of the straight-through vehicle was set at the design speeds of 50 km/h and 60 km/h. Furthermore, to be on the safe (high speed) side, speeds of 35 km/h and 45 km/h were set by looking at multiple situations in which the vehicle enters the sidewalk under different timing scenarios for the collision with the right-turning vehicle.

The angle of entry at which a straight-through vehicle that collided with a right-turning vehicle would enter the sidewalk connected to the crosswalk in a standard road structure of the general national road or prefectural road class in urban area, was set to 15˚.

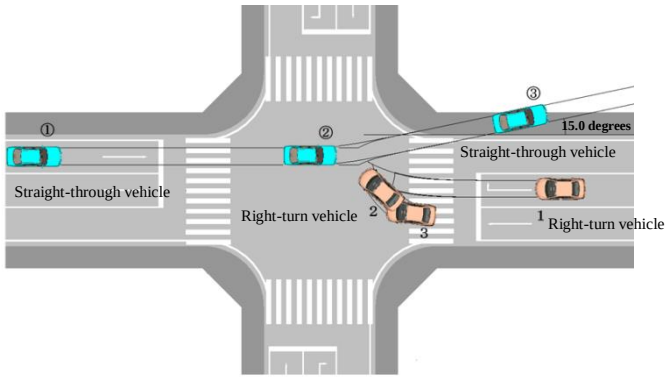

Fig.: Behavior of a straight-through vehicle that collided with a right-turning vehicle

4. Study on evaluation method of strength performance, etc. (collision experiment)

In order to verify the evaluation method of strength performance, etc., a collision test was conducted with actual vehicles under the collision conditions shown in the **table**. In this test, we decided to make a prototype of a H-type bollard, which was made of easily available materials and products, and structurally designed to be shallowly embedded in order to reduce the impact on underground structures in the sidewalk in consideration of practical use. At NILIM's collision test facility, four prototype H-type bollards of a practical structure were arranged (1.5 m apart) on a sidewalk connected to a crosswalk, and struck by a vehicle (passenger car) under the collision conditions of type H_B (see **Table**). Two out of the four H-type bollards were contacted by the vehicle. The vehicle ran up on the first bollard and was pushed back by the second one, and did not enter the sidewalk to a large degree, which was a good result (**Photo 2**). Through this test, we summarized the detailed procedure for evaluating the strength performance and proposed a practical structure for H-type bollards.

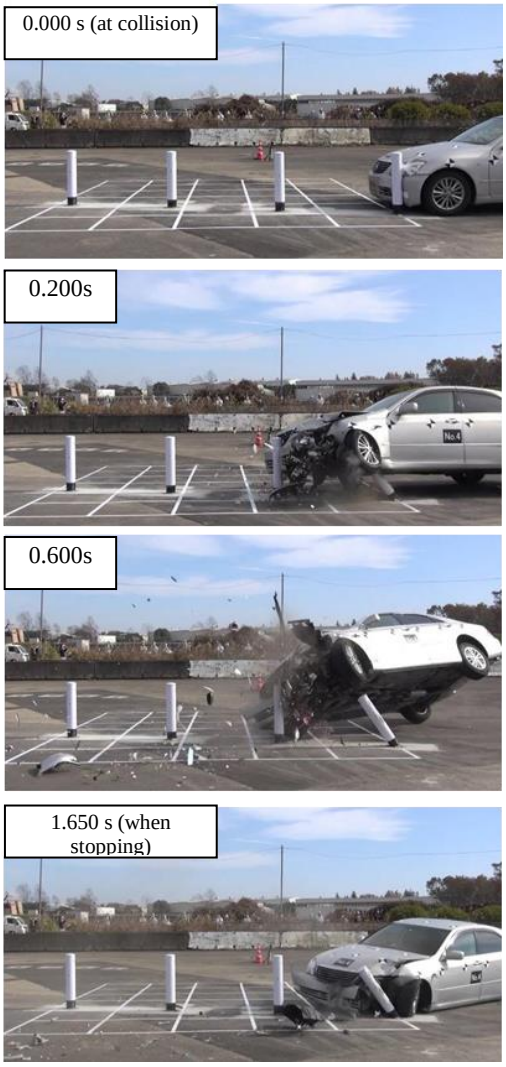

Photo 2: Test situation (Bollard stopped vehicle entry)

5. Conclusion

This paper mainly introduced the study on the strength performance of bollards. Please refer to the Handbook for the concepts of installation, structure, etc. We plan to continue the study on how to solve the issues of bollards and other traffic safety infrastructure.