EVALUATION OF MOVABLE BARRIER FOR SEPARATING CONTRAFLOW LANES FROM FREEWAY LANES

Prepared for

State Department of Highways and Public Transportation
District 18, Dallas

by

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Introduction

TTI was requested to conduct an independent evaluation of a movable concrete barrier system, manufactured and marketed by Barrier Systems Incorporated, Sausalito, California. The barrier is being considered for use on the East R. L. Thornton Freeway in Dallas to separate traffic on contraflow high-occupancy vehicle lanes. If the barrier is used, it will be transferred laterally about 20 ft. each move. Two barrier installations are being considered; one for the inbound traffic, 5.2 miles in length, and one for the outbound traffic, 3.3 miles in length, to be placed on either side of an existing permanent median barrier. One installation would be moved out and back for morning peak traffic and the other would be moved out and back for the evening peak traffic.

Factors considered in the evaluation included the safety implications and crashworthiness of the system, feasibility of moving the barrier the required lateral and longitudinal distances, time required to move the barrier, reliability of the system, unit cost of system to purchase and operate, treatment of barrier ends, and storage of transfer vehicles. Operational benefits associated with the movable barrier are addressed in other TTI reports.[1]

Approach

The scope of the present effort was limited to a review of pertinent literature and applicable performance guidelines and discussions with individuals and agencies having knowledge of various aspects of the system. The literature reviewed included the following:

"Movable Concrete Median Barrier: Risk Analysis of Deflection into Opposing Traffic", James E. Bryden, and Nicholas J. Bruno, Research Report 145, New York State Department of Transportation, December 1988.

Excerpts from a draft report by California Department of Transportation concerning a crash test analysis of the movable concrete median barrier (provided by Roger Stoughton of Caltrans).

"Crash Test Evaluation of a Movable Concrete Construction Barrier," Eric F. Nordlin, paper presented at the Annual Meeting of the Transportation Research Board, January 1987.

"Auckland Harbour Bridge Moveable Lane Barrier Feasibility Report," Consultancy Services of the Works and Development Services Corporation, Auckland, New Zealand, February 1989.

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[1] "East R. L. Thornton Freeway, High-Occupancy Vehicle Lane Project, Candidate Intermediate Action Project." Prepared by TTI for SDHPT and DART, February 1989.

Meetings were held with the following individuals:

James E. Bryden, Civil Engineer III, New York Department of Transportation, January 23, 1989. The main topic of discussion was the study by Bryden listed above. Meeting was held in Washington, D.C. during the Annual TRB meeting in January 1989.

John Duckett and C. H. Hughes, Barrier Systems, Incorporated, February 9, 1989. Discussed capabilities of barrier system in relation to the East R. L. Thornton application, uses of system for other applications in other parts of the U.S. and other countries, and cost estimates. Meeting was held in College Station, Texas.

Paul Hardin, Project Engineer, Bill Bassett, Attorney, John Fisher, Senior Transportation Engineer, and John Markey, District Traffic Engineer, all with the California Department of Transportation, March 8, 1989. Hardin, Fisher, and Markey are in District 11, San Diego, and Bassett is located at the main office in Sacramento. The discussion centered around the planned use of the movable concrete median barrier on the Coronado Bridge in San Diego. Meeting was held at the district offices in San Diego, California.

Roger Stoughton, Senior Materials and Research Engineer, Doran Glauz, Associate Materials and Research Engineer, Sue Hawatky, Assistant Transportation Engineer, Joanna Groza, Junior Civil Engineer, and Ed Tye, Assistant Traffic Engineer, all with the California Department of Transportation, March 10, 1989. Discussions were held concerning a full-scale crash test program conducted by Caltrans on the movable concrete median barrier. The meeting was held at the Caltrans Transportation Lab in Sacramento, California. A visit was also made to Rio Vista, California the same day to observe the barrier system and a demonstration of its movement by a transfer vehicle. John Duckett and Steven Peek of Barrier Systems, Incorporated, conducted the demo.

John V. Blain, Jr., James F. Loper and Mary E. May, SDHPT, Tom K. Ryden and Trip Brizell, DART, Carol H. Walters and Daniel Rathbone, TTI, and John W. Duckett, Barrier Systems, Inc., May 11, 1989. During this meeting, Ross of TTI presented results of the present evaluation study. A video tape was shown of full-scale crash tests of the movable barrier conducted by the California Department of Transportation. Issues discussed with regard to the movable barrier included crashworthiness, treatment of barrier ends, storage and maintenance location for the transfer vehicles, potential problems with creep following repeated barrier transfers on horizontal and vertical curves, reliability of the system, ability of the transfer vehicle to make variable lateral movements of the barrier due to a variable median width, and costs associated with the purchase, operation and maintenance of the system. The meeting was held at the DART offices in downtown Dallas.

Findings

Impact performance. The first reported crash tests of the movable barrier system in the U.S. were those by Nordlin. A series of 13 tests were made with vehicles ranging in size from 1800 lb. to 5100 lb., impact angles ranging from 7 deg. to 25 deg., and impact speeds ranging from 43 mph to 60 mph. With one exception, the barrier contained and redirected each test vehicle. There was a structural failure in a steel hinge connection in one of the more extreme tests, allowing the barrier to separate and undergo large displacements. Analysis of the hinge showed it to have an inferior weldment. In a subsequent test at even more extreme impact conditions the system contained and directed the vehicle with no barrier failure. Maximum deflection of the barrier in these tests ranged from 1.25 in. for a 1800 lb., 7 deg., 47 mph impact to 60.75 in. for a 5100 lb., 25 deg., 57 mph impact. As a result of these tests, it was concluded that the barrier was acceptable for use on construction projects on an experimental basis. It was recommended that the lifting cap, at the top of the barrier segment, be strengthened by making it wider and by the addition of more steel reinforcement.

Caltrans conducted a series of six tests on the movable barrier system subsequent to those of Nordlin. The test program was completed in mid-1988. One of the reasons for these tests was to evaluate the performance of the barrier for potential use on the Coronado Bridge in San Diego (see further discussions below). In the first two tests involving 4000+ lb. vehicles impacting at 60 mph and impact angles of 15 deg. and 25 deg., structural failures of the lifting cap were again observed. It was concluded that additional widening of the cap was needed and that the welded wire fabric use in the barrier should be replaced by more substantial and conventional re-bars. After these changes were made, four more full-scale crash tests were performed. Vehicles ranging in size from 1900 lb. to 4370 lb. impacted the barrier at speeds of approximately 60 mph and angles ranging from 15 deg. to 25 deg. There were no structural failures of the barrier. Deflection of the barrier ranged from 1.8 ft to 3.7 ft. The Structural Adequacy and the Occupant Risk criteria of NCHRP Report 230 were satisfied in each of the four tests. The Vehicle Trajectory criteria of Report 230 were not satisfied in that the exit angle and/or speed change for each test exceeded recommended limits.

Four demonstrations were also made during the course of the Caltrans study. Those involved the transfer vehicle straightening the deflected barrier after a crash test (barrier had been deflected about 2.25 ft.), the transfer vehicle transporting, assembling and transferring barrier on 1400 ft. radius with a 12% cross slope, transfer vehicle transferring barrier on a 4% to 5% longitudinal grade, and the manual movement of the barrier to adjust minor misalignments. According to Caltrans, the demos showed that the transfer vehicle was capable of easily performing each of the assigned tasks. The time required to do these tasks will depend to some extent on the skill and experience of the transfer vehicle operator. It was reported that for conventional transfers the vehicle traveled at about six miles per hour. Some creep of the barrier down hill was observed with each transfer, but when tethered at the upstream end, the creep could be restricted. The following is taken from a Caltrans memo concerning the test program:

> "In conclusion, the MMB tested in tests numbered 443, 444, 445 and 446 performed its intended function well. The barrier is easily transferred with a self powered transfer vehicle and it can be moved easily by a single person with a pry bar. It smoothly redirects large and small cars impacting at approximately 60 mph with minimum risks to occupants and minimal generation of debris. This barrier can prevent serious head-on collisions when deployed as a median barrier. It can also provide secure protection

for workers when deployed as a construction zone barrier. Although there is lateral deflection of the barrier, slight protrusions of the barrier into the protected zone is generally more desirable than uninhibited intrusion of a fast moving vehicle into the protected zone."

"The MMB has proven to be a crashworthy barrier; therefore, it is recommended that it be considered for experimental use in locations where it will be of benefit. If the first installations are in a construction application, operational experience can be gained by the department before a permanent barrier is installed. When planning a location for using this MMB, consideration must be given to the expected lateral displacement under impact."

Another key safety feature that must be addressed is the proper treatment of the barrier ends. Desirably the ends will either be safely shielded from traffic by a permanent barrier or will be offset a minimum of 30 ft. from the edge of the travelway with an accompanying flared section having a flare rate meeting AASHTO recommended values (see 1977 AASHTO Barrier Guide).

In the study by Bryden, the movable barrier was examined for use on the Tappan Zee bridge on the New York State Thruway for a reversible-lane configuration. It is a 3-mile, seven lane, heavily traveled bridge providing major commuter access to the New York metropolitan area. The study was made to evaluate the risk of secondary collisions with opposing traffic resulting from impact deflection of the movable barrier, considering geometric and traffic conditions on the bridge and the barrier's deflection characteristics. It was concluded that the risk of interference with opposing traffic appears to be low, occurring in only a small percent of all impacts on the barrier. It is noted that very conservative estimates were made on the number and severity of collisions with the barrier. The risk of impacts with a deflected barrier for the East R. L. Thornton Freeway application would be considerably less than the Tappan Zee bridge for two reasons; (1) reduced volume of traffic on the reverse-lane side of the barrier, and (2) the added escape area in the median for a driver in the reverse lane to make an evasive maneuver.

Operational considerations. With regard to moving the barrier 20 ft. laterally, the manufacturer assures that this can be accomplished by increasing the overall length of the transfer vehicle and by "crabbing" the vehicle as it moves longitudinally along the roadway. Another question that has been raised concerns the ability of the transfer vehicle to provide a variable lateral transfer, which would be necessary because of the variable median width resulting from piers or other structures in the median. The manufacturer again assures that this can be done by changing the crab angle as the transfer vehicle progresses along the road. It is not clear, however, the extent to which the crab angle can be changed. This needs to be clarified by the manufacturer and demonstrated to the satisfaction of DART/SDHPT. It is believed that problems with the accurate lateral placement of the barrier can be minimized by the use of a remote controlled transfer vehicle, guided by wires embedded in the pavement.

Based on all reported data and information from the manufacturer, a transfer of the barrier for the East R. L. Thornton Freeway application should take a maximum of 1 1/2 hrs. The average speed of the transfer should be about 5 mph.

Since the transfer vehicles cannot be safely and quickly driven on the freeway for any appreciable distance, it is highly desirable that provisions be made to store them in close proximity to the ends of the barrier. The preferable storage location would be in the median if space can be made available.

Reliability. The primary measure of the system's real-world reliability when used as a permanent treatment comes from the France experience. A system similar to the proposed system has been in operation in Paris for approximately 2 1/2 years. The barrier is moved twice a day over its 2.8 km length via a remote controlled transfer vehicle. According to Barrier Systems, Inc., the system used in Paris has been extremely reliable with no significant problems. Applications of the system in the U.S. have been in construction zones only, with uses in Texas, Oklahoma, Illinois, Pennsylvania, North Carolina, and Florida. The writer had a brief discussion with J. R. Stone, District Engineer, SDHPT, Ft Worth about their experience with the barrier in work zones. He reported that the barrier was performing in a very acceptable manner. Oklahoma reports satisfactory performance of the system, having moved the barrier in excess of 120 times according to the manufacturer.

Caltrans is apparently convinced of the reliability of the system since they are proceeding with plans to use it on the Coronado Bridge in San Diego, California. The bridge is about 2 miles in length and has five lanes. It has 6% cross slopes in some locations with a 5% maximum grade. It also has a horizontal curve with a radius of about 1400 ft. Plans call for four transfers of the barrier a day. It will be positioned to form a 2-3 split during morning and evening peaks and positioned in the middle of the middle lane between the peaks. Some concern was expressed by Caltrans engineers about the tendency of the barrier to creep on vertical or horizontal curves after repeated transfers.

The writer had a telephone conversation with John Marlow, Senior Equipment Engineer, Caltrans concerning his evaluation of the transfer vehicle and its reliability. He reported that the vehicle appeared to be overdesigned in many respects with built in redundancy. He was convinced that it would be quite reliable and he was satisfied that the fabricator of the vehicle (a company called Blackwelder) had a proven record in fabricating heavy equipment. His only concern was about the pneumatic tires on the vehicle and the possibility of a flat tire at a critical time.

Costs. The following estimated unit costs were provided by the manufacturer during the February 9, 1989 meeting:

Barrier - $67 per foot
Transfer Vehicle - $225,000
Operation of Transfer Vehicle - $55 per mile per move

In a subsequent meeting on May 11, 1989 the manufacturer advised that the above cost of the barrier and transfer vehicle were for a construction zone barrier system. For the present application the manufacturer advised that the approximate costs would be as follows:

Barrier - $134 per foot
Transfer Vehicle - Variable, depending on accesories and operating conditions. Cost would definitely exceed $225,000.

Summary

Based on the above information, it is the writer's opinion that the movable concrete barrier manufactured by Barrier Systems, Incorporated, will provide a safe and reliable means of separating freeway traffic from contraflow lanes, with the following provisos:

(1) The ends of the barrier can be safely shielded or properly flared and located a safe distance from traffic;

(2) The transfer vehicle can be properly crabbed to provide a variable lateral transfer distance to accommodate variable median widths (the manufacturer should demonstrate that this can be done);

(3) Repeated transfers of the barrier on vertical or horizontal curves will not result in adverse and unacceptable creep in the barrier (the manufacturer should stipulate that this will not be a problem); and

(4) The transfer vehicles can be stored and serviced at a location in close proximity to the ends of the barrier, preferably in the median, and the location can be easily and safely accessed by operating and service personnel.

It is noted that the present study did not address the cost effectiveness of the proposed barrier system. A benefit/cost study should be made prior to implementation of the system.