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May 5, 1971
H-2-64

MEMORANDUM TO: J. R. Harbison
State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report, Interim; "Experimental Installations of Impact Attenuation Devices"; KYHPR-71-64; HPR-1 (6), Part II

Quite some time ago, interest mounted regarding a device (Tor-Shok) which was capable of arresting a fast-moving automobile in a survivable way. While plans for a trial installation were being drawn, several other developments emerged. The Fitch-type barrier offered convenience of installation, and the Rich-type could be fitted into minimal space situations. The FHWA invited experimental installations and evaluations. At first, they were limited to sites already constructed but were later extended to future construction. Six existing sites were programmed on an experimental basis -- under force account provisions. In mid-summer, 1969, the Assistant State Highway Engineer for Pre-Construction appointed a committee consisting of the Directors of Design, Bridges, Maintenance, Traffic, and Research to overview and coordinate all projects. Later, the FHWA dismissed the experimental status of the barriers but invited evaluation-and-performance reports. Meanwhile, the Research Division advanced a research proposal involving intensive surveillance of several installations. The FHWA approved that proposal July 28, 1970.

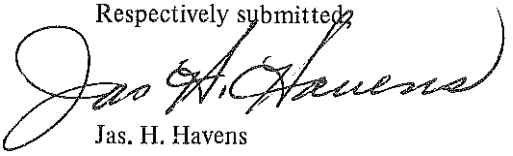
Early in 1970, the Committee charged the Research Divisions to survey the entire interstate system and to submit recommendations concerning safety revisions needed at gore sites. Only those portions opened to traffic were inspected then; some portions not then open to traffic were added in a subsequent report. Those sites not requiring a soft barrier but needing other corrective measures are being included in other safety projects.

The report submitted herewith was prepared to document programs toward the objectives of the research study and to provide a convenient reference for the Committee.

At a recent meeting, the Committee resolved to "design away" - when possible -- any situation otherwise requiring a cushion-type barrier. Contour grading is appearing in current plans. On-structure splits are being designed to move the gore-wall more remote from the apex of the bifurcation ; also, the grade is being continued as far as possible to present a better view to the driver.

Consequent reports will be forthcoming.

Respectively submitted,



Jas. H. Havens
Director of Research

Enc.

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All District Engineers

Research Report
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EXPERIMENTAL INSTALLATIONS OF IMPACT ATTENUATION DEVICES

INTERIM REPORT

KYHPR - 71 - 64; HPR - 1 (6), Part II

by

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Federal Highway Administration

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INTRODUCTION

The expanding system of limited access, multilane highway facilities in the United States has enhanced traffic service between many varied origins and destinations. As a result, these facilities have not only reduced travel times and travel costs, but have generated additional travel by virtue of their technological splendor. The increasing dominance of multilane highways in terms of percentage of total vehicle miles travelled has produced a revolution in highway engineering philosophy. Higher design speeds, increased lane widths, lateral separation of opposing traffic streams, absence of passing restrictions, and increased traffic capacities were attributes intuitively sought. An ironic result is the emergence of new accident styles on roadways which had as their specific purpose the reduction of accidents. Dominant among these new styles was the "single vehicle ran off the road" type.

Recent investigations (1) have shown that this accident mode may be the largest single contributor to fatalities on limited access, multilane facilities. Contributing to the preponderance of this accident type are some seemingly minor but potentially deadly elements of the roadway. Previous studies have been concerned with bridge piers located in the median (2), the location of median crossovers (3), and the horizontal and vertical dimensions of medians themselves. (4). Problems have been created by rigidly fixed objects such as bridge walls or massive sign standard bases located in the gore area of bifurcating roadways and exit ramps. Figure 1 illustrates a typical problem area.

Several contributing factors compound the problem at these locations. Physical features of the roadway associated with grade separations include bridge walls and pier supports. Many exit ramps are located in such a position that there is a sparsity of clear area between the diverging roadways. The complex interpositioning of exit roadways and parapet walls often results in a situation similar to that shown in Figure 1.

The preferability of a clear gore area, such as is shown in Figure 2, is related to the manifold psychological reactions of a driver to roadway situations. Multilane highway facilities and their attendant features which require driver decision and commitment are sometimes momentarily confusing. Initially, this was attributed to the novelistic quality of the road type. It was hypothesized that as the great body of the motoring public was exposed to these features, drivers would instinctively comply and compensate. Such, however, has not been altogether the case. A report of a special AASHO Traffic Safety Committee, February 1967 (11) (the "Yellow Book"), enumerated 19 considerations pertaining to safety in the design of the roadways.

Although designs and signing are being revised, the problem of vehicle encroachment into gore areas remains largely unabated. The design standards to which the above statement alluded have increasingly called for a greater recovery area within the gore to enable an errant driver to survive his mistake. Existing sites are subject to correction. Revised signing and improved visibility have been somewhat effective. However, situations exist which are poorly designed (by current design standards) and for which signing changes have not been the solution. Drivers continue to commit errors, and the result is all too often an accident statistic.

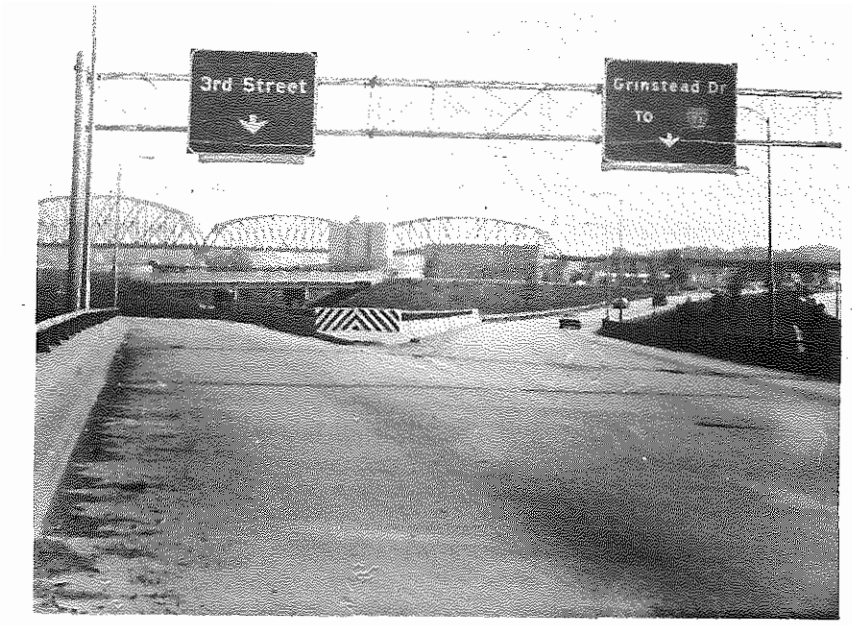


FIGURE 1. Dangerous Gore Configuration

FIGURE 2. Adequate Gore Area

RESPONSE TO THE PROBLEM

The malady of bridge walls and sign supports restricting the clear zone within the gore area between diverging traffic lanes has been recognized as such by a diverse spectrum of highway oriented persons. Research agencies, highway administrators, engineers, and even race car drivers have responded to the problem with several variations of the singular concept of energy absorption through impact attenuation. The concept is basically simplistic - to provide a survivable rate of deceleration to the occupants of the crash-oriented vehicle by increasing the distance over which the vehicle comes to rest. A vehicle travelling at 50 mph which impacts a fixed object decelerates over virtually zero distance and during a time period which can be expressed as a small fraction of a second. By definition,

$$a = \frac{d^2s}{dt^2}, \text{ or } s = \tfrac{1}{2} at^2$$

where a is the acceleration, s is the distance, and t is time. If s is expressed in feet and t in seconds, then the units of a are feet per second per second (ft/sec^2). In this case, it is deceleration with which we are concerned, and this can be expressed mathematically as negative acceleration. From the equation, it can be seen that increasing the time required for a deceleration to zero will decrease the rate of deceleration. Thus, the concept emerged of increasing the time of deceleration by increasing the distance required to decelerate, and thereby reducing the rate of deceleration to a survivable level. In practice, the parameters in this equation are approximately as follows: a = -7 g's = -226 ft/sec^2, s = 20 feet, and t = 0.3 second.

Based on the above theoretical concepts, several types of energy absorbing safety barriers were developed. The energy absorbing description could be better described as momentum transference since deceleration is accomplished by imparting the momentum of the moving body to a medium within the crash barrier, such as sand or spewing water. A review of the various types of devices thus developed and the experiences gained to date was conducted by the Division of Research in 1969 (5). As a result of this study, two types of barriers were selected to be installed on an experimental basis at selected gore locations on Kentucky highways. These were the HI-DRO CUSHION CELLS, developed by John Rich Enterprises, Inc. of Sacremento, California, and FITCH INERTIAL BARRIERS developed by FIBCO, Inc., of Hartford, Connecticut. Details of these two types of barriers can be found in the referenced report (5) and also in the respective manufacturer's promotional literature (6, 7).

SELECTION OF SITES FOR BARRIER INSTALLATIONS

Six specific locations had been under consideration since early 1969. They are:

1. Campbell County; I 471 - 5th Street interchange, Gore at Ramp "L".
2. Jefferson County; I 64 (Riverside Expressway) 9th Street interchange:
   (a) Gore at Ramp 3
   (b) Gore at Ramp 4

3. Jefferson County; Kennedy interchange (I 71 - I 64 - I 65):
   (a) Southbound secondary gore between Ramps 4 and 8
   (b) Northbound secondary gore between Ramps 3 and 6
   (c) Mainline exit northbound

The first three listed above were in the design stage at that time, while the latter three were existing sites. In March 1969, the Division of Research was committed to monitor the installation of, and evaluate the subsequent benefits deriving from, safety barriers at five of these six locations. (No decision was reached at that time regarding the Campbell County location.) Arrangements were then made with the John Rich Company to present HI-DRO CUSHION CELL designs for the three existing locations within the Kennedy Interchange. At that time, consideration was given to installing a TOR-SHOK device (1, 5, 8, 9) in the gores on the Riverside Expressway -- but this type of device was rejected in favor of the inertial types.

In mid-summer 1969, a departmental committee representing the Divisions of Bridges, Maintenance, Traffic, Design, and Research was formulated to establish a complete list of locations at which the installation of a momentum-transferring safety barrier was deemed appropriate. As a result of the meetings of this committee, four sites (additional to those already enumerated) were designated. These were:

4. Kenton County; I 275 - US 25 & US 42 intechange, Gore between Ramps A and C
5. Jefferson County; Jefferson Freeway - Westport Road interchange, Gore at Ramp 5
6(a). Jefferson County; I 264 Shively interchange with US 31W, Gore at Bridge No. 7 (this gore area was selected at the request of the Federal Highway Administration).
7. Kenton County; I 75 - Fifth Street interchange, Gore at southbound exit ramp.

Additionally, tight gore areas on the Louisville North-South Expressway were recommended to be graded level with median waste material, and guardrails were to be turned on a large radius, and thereby provide space for possible future installation of some type of momentum-transferring safety barrier. This work was to be performed as part of a programmed widening project on this particular roadway section. Furthermore, the committee, while agreeing that a safety barrier was needed at the two locations on the Riverside Expressway, decided that recently observed crash tests of the TOR-SHOK device at the Federal Highway Administration Chicago office 4-S Safety Seminar indicated that this particular device was not sufficiently documented to warrant its installation at this time. Subsequent committee action designated a second gore area within the interchange designated above as 6 (a). This was:

6(b). Jefferson County; I 264 Shively interchange with US 31W, Gore at Ramp No. 7.

Early in the calendar year 1970, it was decided to survey all existing interstate facilities within the state, as well as all those in the design stage, to ascertain if any deficiencies existed with respect to gore geometry. The Division of Research was charged with the responsibility of appraising the existing gore locations. During January, three research engineers travelled the existing interstate facilities and examined all gore areas. Such items as guardrails, sign standards without

breakaway bases, protruding drainage structures, and sight obstructions were evaluated; safety barriers were considered only where other revisions would not suffice. The purpose of this survey was to include these items in the 1970 estimates of "Cost of Completing the Interstate System in Kentucky"; toll road facilities were not included in this survey.

The site shown in Figure 2 was without noticeable defect. Of all the gores inspected, eight were found at which the installation of a safety barrier was the most satisfactory method of renovation. Those are itemized as follows:

8. Franklin County; I 64 - US 127 interchange:
   (a) Gore at westbound exit from I 64 to US 127
   (b) Gore at eastbound exit from I 64 to US 127
9. Shelby County; I 64 - KY 395 interchange, Gore at eastbound exit from I 64 to KY 395
10. Fayette County; I 75 - US 25 & US 421 interchange, Gore at northbound exit from I 75 to US 25 and 421
11. Whitley County; I 75 - US 25 interchange:
   (a) Gore at southbound exit from I 75 to US 25
   (b) Gore at northbound exit from I 75 to US 25
12. Jefferson County; I 65 - Chestnut Street interchange, Gore at northbound exit from I 65 to Chestnut Street
13. Jefferson County; I 65 - St. Catherine Street interchange, Gore at southbound exit from I 65 to St. Catherine Street

The survey of those sections of roadway in the design stage revealed no additional deficient locations.

Over a period of several months early in 1970, three additional existing gore locations were denoted by Research personnel as being appropriate locations at which to install a safety barrier. These are:

3 (d). Jefferson County; Kennedy interchange (I 71 - I 64 - I 65), Mainline exit southbound
14. Jefferson County; I 64 - I 264 (New Albany) interchange, Northbound directional split from I 264 to I 64
15. Jefferson County; I 64 - 3rd Street interchange, Gore at westbound exit from I 64 to 3rd Street

Of the above-mentioned locations, all are existing locations, but only the first, 3 (d), is completely open to traffic. At the other two locations, one branch in the gore is currently closed to traffic and, therefore, is not a problem at this time.

Finally, the three gore areas most recently considered as warranting energy absorbing barriers are listed below:

2 (c). Jefferson County; I 64 (Riverside Expressway)-9 th Street interchange, Gore between Ramps 1 and 2A

16. Jefferson County; Riverside Expressway - 22nd Street interchange, Gore at eastbound exit from Riverside Expressway to 22 nd Street
17. Campbell County; I 471 - I 275 interchange, Gore between I 471 southbound and Ramp F on I 275

In summary, it can be noted from this chronological listing that there are 25 gore areas existing or in the design stage at which the installation of a momentum-transferring safety barrier has been considered. For easy reference these gore areas are listed in APPENDIX A.

VEHICLE-ACTUATED CAMERA INSTALLATION

The research evaluation of the barrier installations seemed inseparable from accident histories and analyses of case records. Movie-camera surveillance would, of course, record actual collisions with the barriers and permit review of attendant circumstances. The Texas Transportation Institute's experience (10) in installations of this type were reviewed. The first consideration was the selection of a movie camera which could be remotely actuated. Since the camera was to be exposed to the weather, all lighting conditions would be present. A movie camera was found at the Division which generally satisfied these requirements for daylight conditions. The camera chosen was a 16 mm, gun camera, Type N-1, made by Bell & Howell, with modifications by Fairchild Aviation Company. The camera operated on 24 volts, D C, and had running speeds of 16, 32, and 64 frames per second.

The test site chosen was in an interchange where lighting was available. It was hoped that this lighting at night would be sufficient to obtain viewable film. The camera aperature was set for medium light conditions. Rubber, pneumatic tubes connected to air switches were anchored to the pavement or ground ahead of the barrier so that a vehicle crossing the pneumatic tube would trigger the camera through a Potter and Brumfield relay Model KRP 11D and two 12-volt batteries in series. Since it was not feasible to let the camera run continuously once triggered, an Amperite, Time Delay Relay, Model 26C20, was installed in series with the batteries and camera (Figures 3 and 4). In the "ready" position, the two 12-volt batteries are at rest. This specific circuit will remain active for the predetermined time, while the circuit through the air switch is only momentary. Thus, the power circuit to the camera persists for 23 seconds. The 23 seconds was chosen because it seemed to be sufficient time to film a vehicle impenging on the barriers and also to be able to judge the full extent of the damage. Allowing 23 seconds of movie time per trip, the camera was capable of viewing six accidents or encroaching excursions on 50 feet of film.

To determine the exact number of times the system was triggered, a 24-volt, DC, electrical counter, Type E2B65C, was installed in parallel with the camera. This provided an accurate method of determining how many feet of movie film had been used, and how many vehicles had tripped the system after all the film footage had been used.

The first plan was to install the batteries in a steel box, and place them under a bridge behind the gore site (Figure 6). However, the distance from this site to the camera proved to be

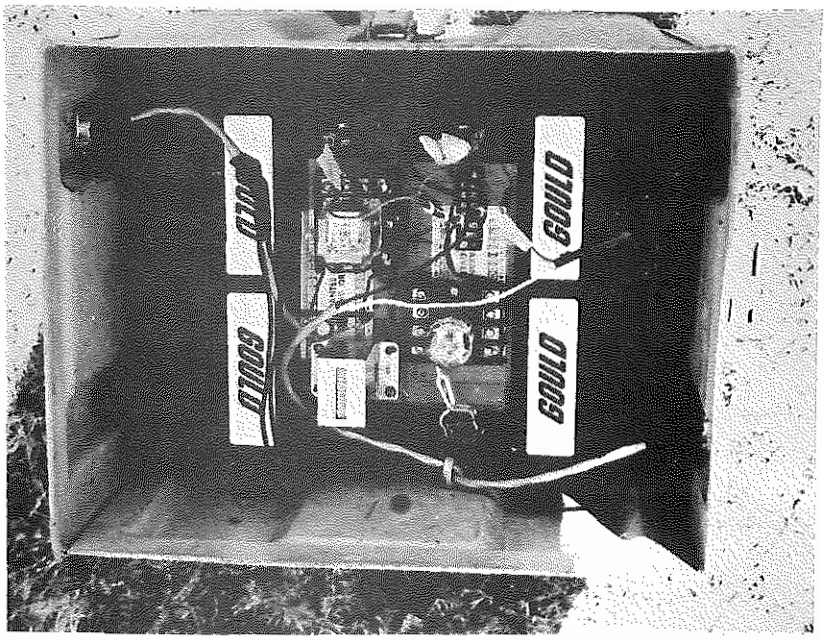
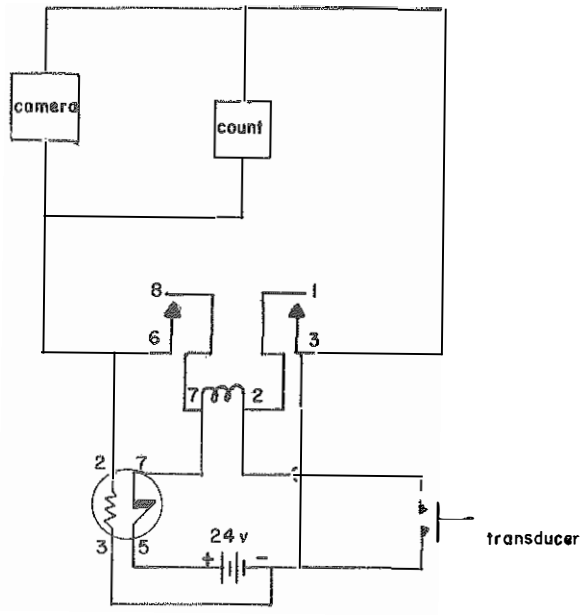


FIGURE 3. Camera-actuating System and Power Supply



READY

FIGURE 4. Electrical Diagram of Apparatus

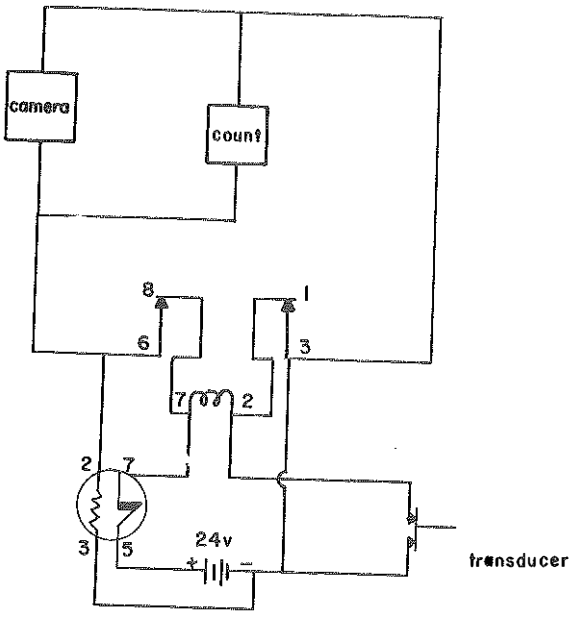


FIGURE 5. Electrical Diagram for Actuation

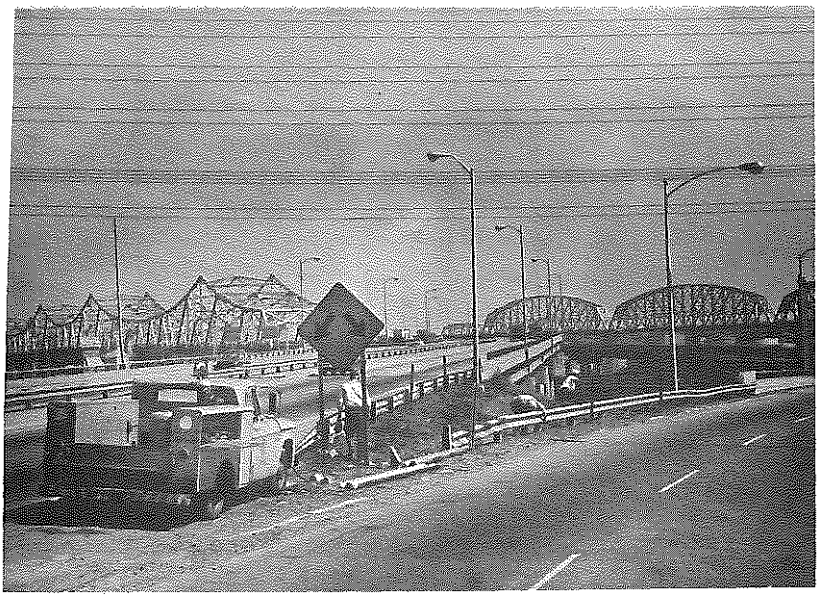


FIGURE 6. View of Site before Revision

too great, offering great electrical resistance. It was found that the camera needed a surge of power to actuate; and to accomplish this, the batteries were placed closer to the camera and chained to an existing guardrail (Figure 7).

The view from the camera of the barriers in question was from above and behind impenging vehicles. This position allows maximum observations of the vehicles as they approach the safety barriers. Also, this was the only feasible existing point of view available. The camera was placed on a portable base attached to the horizontal bars of the overhead sign standard (Figure 8). The right-hand position was chosen for convenience of the camera. The height of the sign above pavement was approximately 25 feet, and the camera itself was positioned 35 feet to the right of the first safety barrier. By previous measurements at the site, horizontal and vertical angles were calculated; and before installation, the angles were preset so that aiming the camera would not be by trial and error and would not be necessary after each servicing (Figures 8 and 9).

The camera housing posed a difficulty; a maximum of light had to be available to the camera; however, a maximum of protection from weather elements was also necessary. The front of the box was made of 1/4-inch plexiglass to allow enough light for the lens and also to provide strength and durability. The remainder of the box was made from 3/4-inch plywood and sealed with a gray plastic paint. The gray was chosen for the housing color so that when placed on the overhead sign, the colors would not be conspicuous. The box was hinged in a lid fashion for ease in servicing the camera. Inside the housing, a small adjustable platform was fitted for the purpose of setting the camera at any desired vertical angle. Attached to this small platform are three steel bars which provide lateral support for the camera.

Initial installation of the system was performed with the aid of a "cherry-picker" truck. This permitted a reasonably quick and safe method of installation. Servicing of the system was planned at least once a week.

WARRANT INVESTIGATION OF SELECTED SITES

Either of two warrants was sufficient to determine the applicability of a safety barrier at a particular gore location. The two warrants established were:

1. the physical appearance of the location, and
2. the accident history of the location

The gores between Ramps 4 and 8, and Ramps 3 and 6, at Site 3, Kennedy Bridge, were deemed appropriate; each fulfilled the requirements of the first warrant. Although no accidents have been reported by the Louisville Police Department at either of these locations, the Kennedy interchange area, in general, has been the site of many accidents, several of which occurred in proximity to the ramps in question. An inspection of Ramps 4 and 8 and Ramps 3 and 6 gave positive proof that these locations had been the scene of several accidents -- which, for various reasons, were not reported to the Louisville Police Department. This positive proof consisted of visible scars, i.e. chipped concrete, large scratches, etc. on the bridge walls.

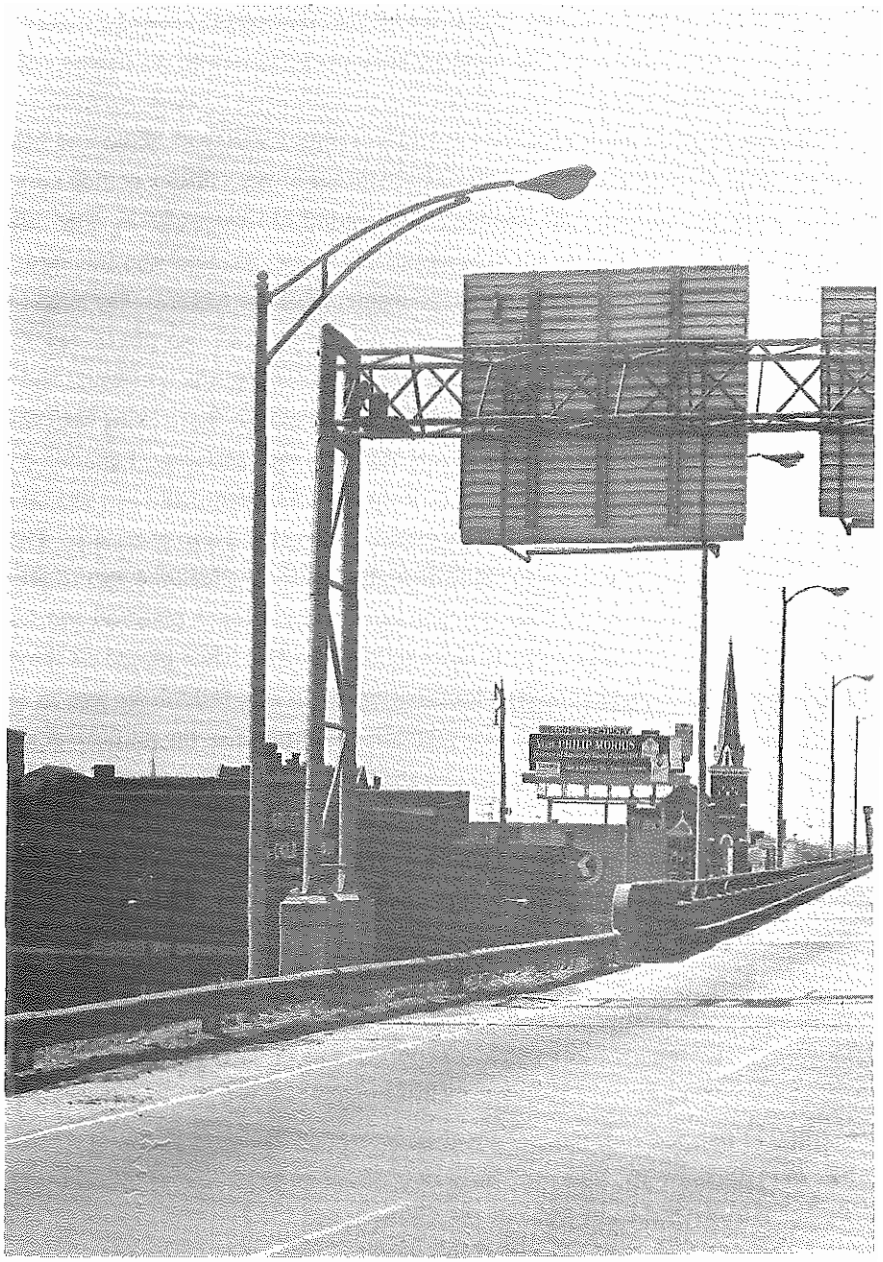


FIGURE 7. Site of Camera and Power Supply

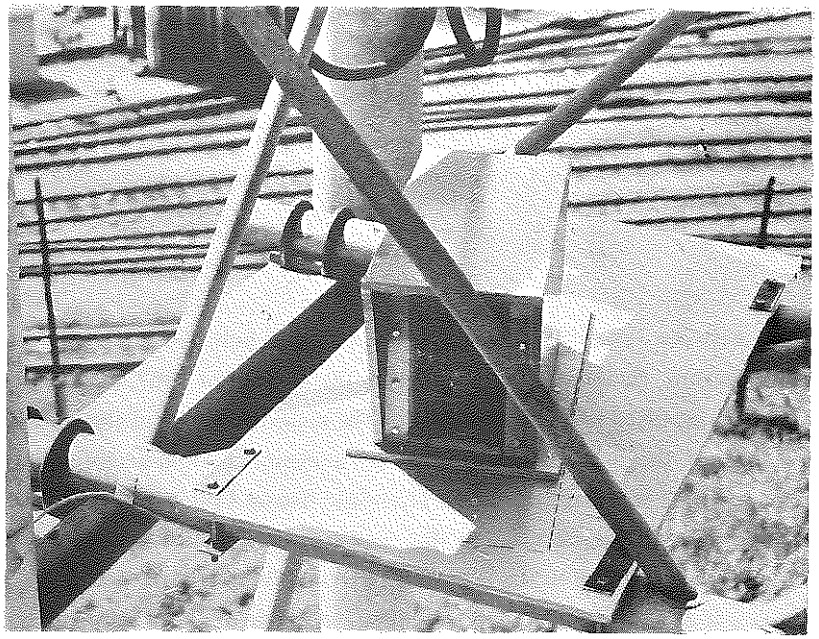


FIGURE 8. Camera Mount without Cover

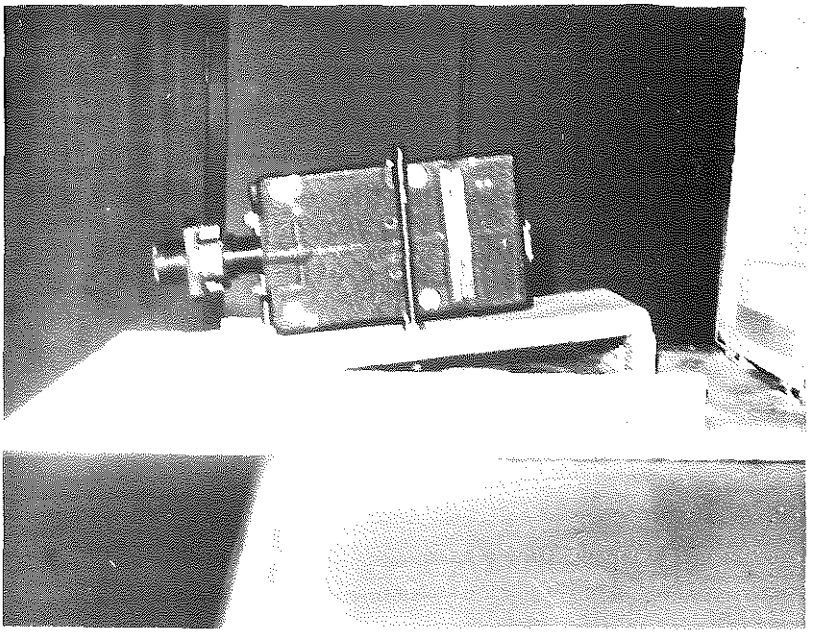


FIGURE 9. Camera - Angle Adjustment

Both warrants applied at 1) the Jefferson County, Kennedy interchange, mainline exit northbound (I 65 northbound at Third Street exit (initial gore)) and at 2) the Kenton County I 75 - Fifth Street exit ramp gore (southbound). The accident summaries for these two locations follow.

I 65, Northbound, at Third Street Exit
(Initial Gore)
Jefferson County

Between July 1, 1967, and July 31, 1970, 24 police-investigated accidents were reported at this location. Of these, three occurred in the last half of 1967, nine in 1968, seven in 1969, and five have been reported as of July 31, 1970. The majority, seven, of these accidents occurred on a Wednesday, although the distribution was relatively uniform, i.e. four accidents on a Monday, three on a Tuesday, seven on Wednesday, four on Thursday, five on Friday, one on Saturday, and none on Sunday. More accidents, five, occurred in May than any other month, though this distribution was also relatively uniform, i.e. five in May, four in March and August, three in January and February, two in June, one in July, November, and December, and none in April, September, and October.

The vehicle in 18 instances was a passenger vehicle, in two instances a four-tire truck, and in four instances a truck with six or more tires. Twenty-one of the drivers were males, while only three were females. The average age of the drivers was 39 years. Ten drivers lived in Jefferson County, two were from other counties in Kentucky, and twelve were from out of state.

There were two fatalities at this location and seven Class "A", i.e. visible signs of injury (bleeding, distorted members, etc.) or victim had to be carried from the accident site. Two were classified as Type "B", i.e. visible injuries other than Type "A" (bruises, abrasions, swelling, limping, etc.), and one injury was classified as Type "C", i.e. no visible injury but complaint of pain or momentary unconsciousness. In 14 of the accidents, there was no indication of injury.

The road surface condition was dry during fifteen of the accidents, wet during eight and snowy or icy during one of the accidents. The weather conditions were clear during eleven of the accidents, raining during eight accidents, and cloudy during five of the accidents. Ten of the accidents occurred in daylight and fourteen occurred in darkness.

Fifteen of the accidents were classified as "fixed object" accidents, seven were classified as "rear-ends", one was a "right-angle", and one was an "oblique" accident.

I 75, Southbound, at Fifth Street Exit
Kenton County

There have been 33 police-investigated accidents at this location between July 1, 1967, and July 8, 1970. Seven of these accidents occurred in the last half of 1967, nine occurred in 1968, eleven occurred in 1969, and six have taken place as of July 8, 1970.

Of these 33 reported accidents, seven were on Sunday, six on Saturday, six on Friday, three each on Thursday, Wednesday, and Tuesday, and five were on Monday. Five accidents

occurred in both September and October, with the remainder being evenly distributed among the other months of the year.

In 30 instances, the vehicle was a passenger car; and in three instances, the vehicle was a truck with six or more tires. In 24 of the accidents, the driver was a male; and in six accidents, the driver was a female. The sex of three drivers was unknown; these three accidents were hit-and-runs. The average age of the drivers was 32 years. Ten of the drivers lived in Kenton County, two were from other counties in the state, and 18 were from out of state.

Twelve of the injuries at this location were Type "A", nine injuries were Type "B", and ten were Type "C". In 20 accidents, there was no indication of injury. There were no fatalities at this location.

The road surface was classified as dry during 20 of the accidents and as wet during the other 13 accidents. The weather conditions were clear during 23 of the accidents and raining during the other ten accidents. One of the accidents took place at dusk, 15 in daylight and 17 in darkness.

Fifteen of the accidents were classified as "rear-ends", six were "obliques", five were "fixed object", five were "single vehicle", and two accidents were "multiple rear-ends."

CURRENT STATUS OF EACH SITE

Accomplishments to date at each of the 25 gore locations are summarized in this section.

Location 1; Campbell County; I 471 - 5th Street interchange

In December 1969, the Division of Research recommended to the Committee on Energy Absorbing Devices that a HI-DRO CUSHION CELL barrier be installed at this site. This gore was in the design stage; and, at that time, this site was relatively short (50 feet) and relatively narrow (a nosed parapet wall). It was for these reasons that a HI-DRO CUSHION CELL was selected. However, since the original design was made, the Division of Bridges moved the parapet wall back approximately 58 feet and rounded the wall to provide a wider backup for any anticipated barrier installation. A FITCH INERTIAL BARRIER was then chosen for this redesigned gore, according to tentative selection criteria used. Figure 10 is a plan-view schematic of the FITCH barrier designed for this location.

Locations 2 (a), 2 (b), 2 (c); Jefferson County; I 64 - 9th Street interchange:

(a) Gore at Ramp 3

(b) Gore at Ramp 4

(c) Gore between Ramps 1 and 2A

Gore locations (a) and (b) will be discussed together since identical comments and recommendations can be applied to each. The recommendation of this Division to the Committee

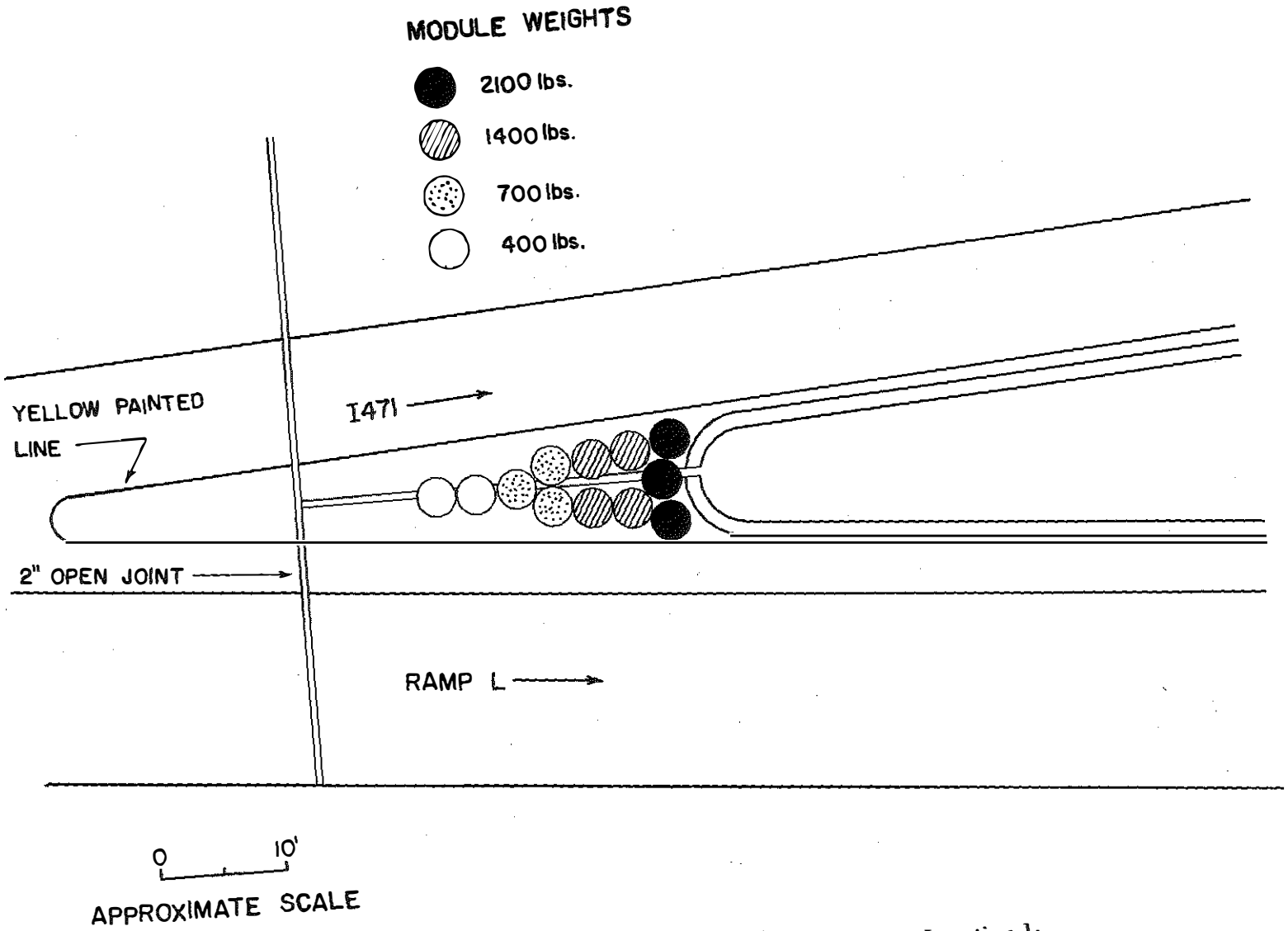


FIGURE 10. Schematic of FITCH System Design for Location 1; Campbell County, I 471 - 5th Street Interchange, Gore at Ramp "L"

included elimination of curbs or raised dividers, a slight rounding of the backwall, and the installation of a Fitch system at each site. In accordance with these recommendations, the Division of Bridges revised the backwall design, and this Division designed a FITCH system for each. Since these locations are in the design stage, the barriers will be installed at the constructed gore site prior to opening of the project to traffic. Figures 11 and 12 show plan views of the designs at Ramps 3 and 4, respectively.

A HI-DRO CUSHION system was recommended for the gore between Ramps 1 and 2A. The system decided upon was the standard, eight-bay unit, Model No. 209800585. Figure 13 shows a plan view of this gore area, and Figure 14 illustrates the HI-DRO CUSHION designed for this location.

Locations 3 (a), 3 (b); Jefferson County; Kennedy interchange (I 71 - I 64 - I 65):

(a) Gore between Ramps 4 and 8

(b) Gore between Ramps 3 and 6

It was the recommendation of this Division that a HI-DRO CUSHION barrier be installed at each of these locations. Preliminary designs had been requested for these gore areas early in 1969, and these were accepted by the Committee. Authorization for the installation of these barriers was requested in January 1970; these are existing locations. In March, a request was sent to the supplier for a firm price quote for the materials. These barriers were installed in early September 1970. Figure 15 shows the gore at the junction of Ramps 4 and 8. The gore between Ramps 3 and 6 was previously pictured in Figure 1. The designs for each of these gores are respectively illustrated in Figures 16 and 17. The actual installations for the gores between Ramps 4 and 8 and Ramps 3 and 6 are pictured in Figures 18 and 19. These gores are also being considered for camera monitoring.

Location 3 (c); Jefferson County; Kennedy interchange (I 71 - I 64 - I 65), Mainline exit northbound

Originally, a HI-DRO CELL barrier was planned for this location. The design suggested by the manufacturer was judged to provide insufficient protection at this unusual gore area. Figure 20 pictures this site as it existed until May 1970. This particular gore had a history of many accidents and had an alarmingly high severity rate. The dual guardrail end-treatment shown in Figure 20 had apparently reduced the severity rate of the accidents at this site but not the frequency. It was decided that an increase in the area was needed between the bifurcating roadways. The HI-DRO CELL barrier would have decreased the gore area and thereby would have caused further constriction. The alternate suggestion was to fill the gore area back nearly to the bridge structures, turn the guardrail on a radius, and install a FITCH barrier. This procedure would not only provide a barrier system but would increase the free area by over 100 feet. The gore area was regraded with the assistance of District 5 to a grade as shown in Figure 21. The FITCH barrier system installed at this gore on August 13-14, 1970 is schematically illustrated in Figure 22. Figure 23 shows the barrier as it now appears. This site is currently being monitored by a vehicle-actuated camera system.

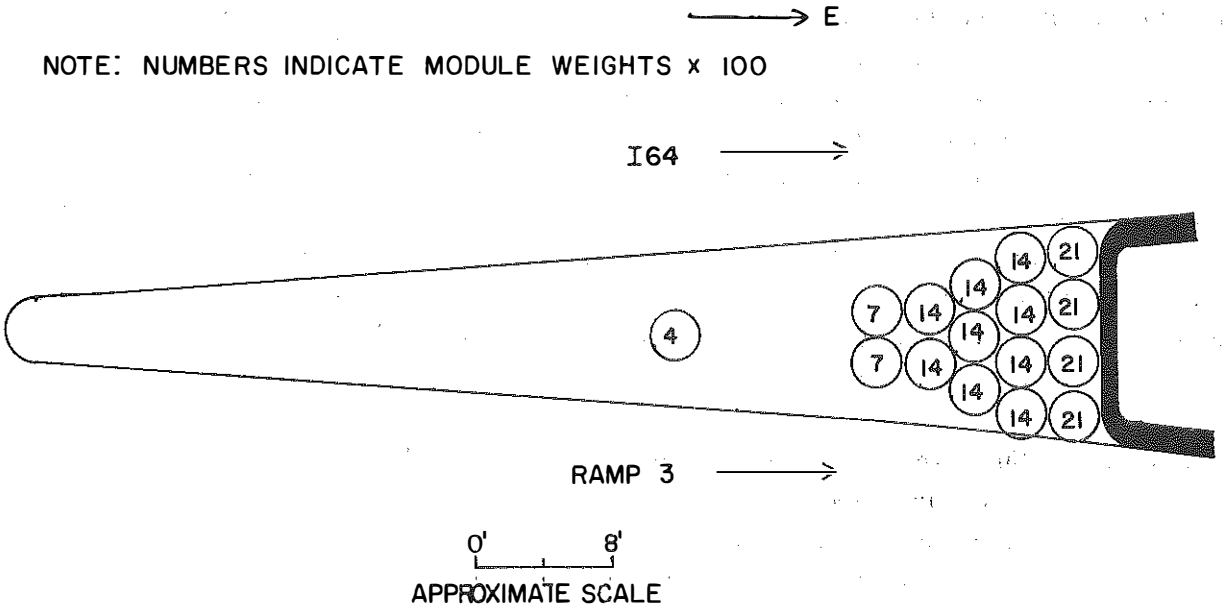


FIGURE 11. Plan View of FITCH System Design for Location 2 (a); Jefferson County, I 64 (Riverside Expressway) - 9th Street Interchange, Gore at Ramp 3

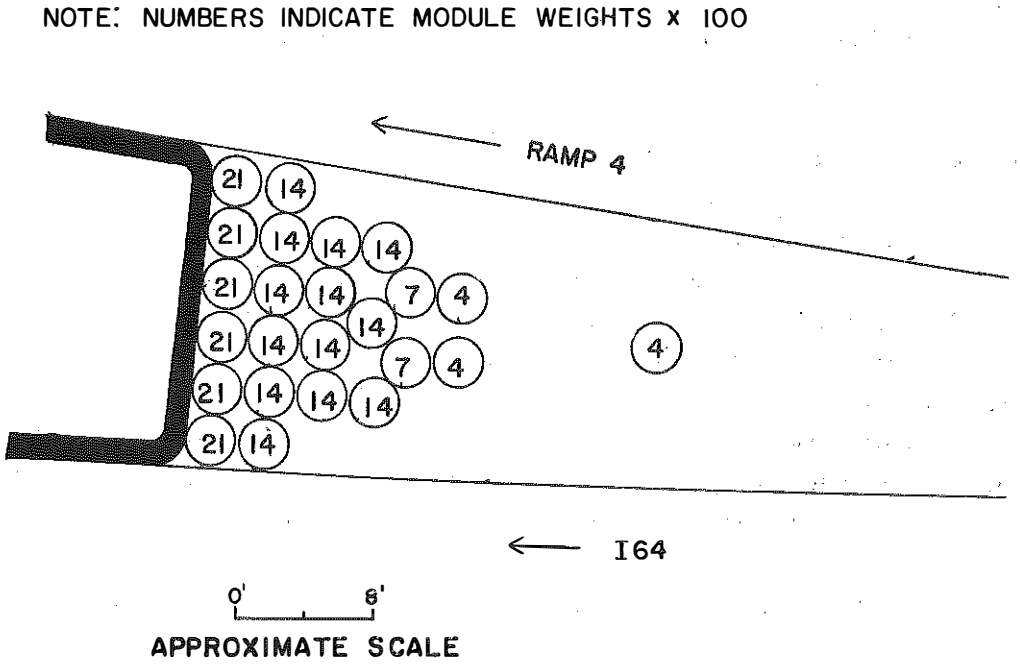


FIGURE 12. Plan View of FITCH System Design for Location 2 (b); Jefferson County, I 64 (Riverside Expressway) - 9th Street Interchange, Gore at Ramp 4

included elimination of curbs or raised dividers, a slight rounding of the backwall, and the installation of a Fitch system at each site. In accordance with these recommendations, the Division of Bridges revised the back wall design, and this Division designed a FITCH system for each. Since these locations are in the design stage, the barriers will be installed at the constructed gore site prior to opening of the project to traffic. Figures 11 and 12 show plan views of the designs at Ramps 3 and 4, respectively.

A HI-DRO CUSHION system was recommended for the gore between Ramps 1 and 2A. The system decided upon was the standard, eight-bay unit, Model No. 209800585. Figure 13 shows a plan view of this gore area, and Figure 14 illustrates the HI-DRO CUSHION designed for this location.

Locations 3 (a), 3 (b); Jefferson County; Kennedy interchange (I 71 - I 64 - I 65):

(a) Gore between Ramps 4 and 8

(b) Gore between Ramps 3 and 6

It was the recommendation of this Division that a HI-DRO CUSHION barrier be installed at each of these locations. Preliminary designs had been requested for these gore areas early in 1969, and these were accepted by the Committee. Authorization for the installation of these barriers was requested in January 1970; these are existing locations. In March, a request was sent to the supplier for a firm price quote for the materials. These barriers were installed in early September 1970. Figure 15 shows the gore at the junction of Ramps 4 and 8. The gore between Ramps 3 and 6 was previously pictured in Figure 1. The designs for each of these gores are respectively illustrated in Figures 16 and 17. The actual installations for the gores between Ramps 4 and 8 and Ramps 3 and 6 are pictured in Figures 18 and 19. These gores are also being considered for camera monitoring.

Location 3 (c); Jefferson County; Kennedy interchange (I 71 - I 64 - I 65), Mainline exit northbound

Originally, a HI-DRO CELL barrier was planned for this location. The design suggested by the manufacturer was judged to provide insufficient protection at this unusual gore area. Figure 20 pictures this site as it existed until May 1970. This particular gore had a history of many accidents and had an alarmingly high severity rate. The dual guardrail end-treatment shown in Figure 20 had apparently reduced the severity rate of the accidents at this site but not the frequency. It was decided that an increase in the area was needed between the bifurcating roadways. The HI-DRO CELL barrier would have decreased the gore area and thereby would have caused further constriction. The alternate suggestion was to fill the gore area back nearly to the bridge structures, turn the guardrail on a radius, and install a FITCH barrier. This procedure would not only provide a barrier system but would increase the free area by over 100 feet. The gore area was regraded with the assistance of District 5 to a grade as shown in Figure 21. The FITCH barrier system installed at this gore on August 13-14, 1970 is schematically illustrated in Figure 22. Figure 23 shows the barrier as it now appears. This site is currently being monitored by a vehicle-actuated camera system.

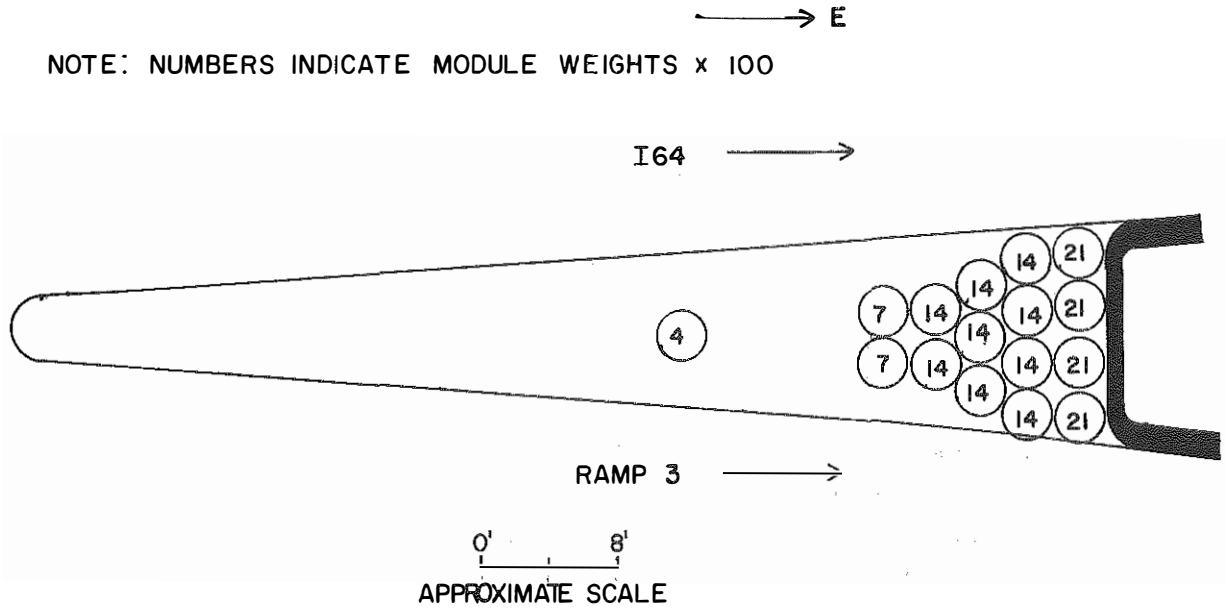


FIGURE 11. Plan View of FITCH System Design for Location 2 (a); Jefferson County, I 64 (Riverside Expressway) - 9th Street Interchange, Gore at Ramp 3

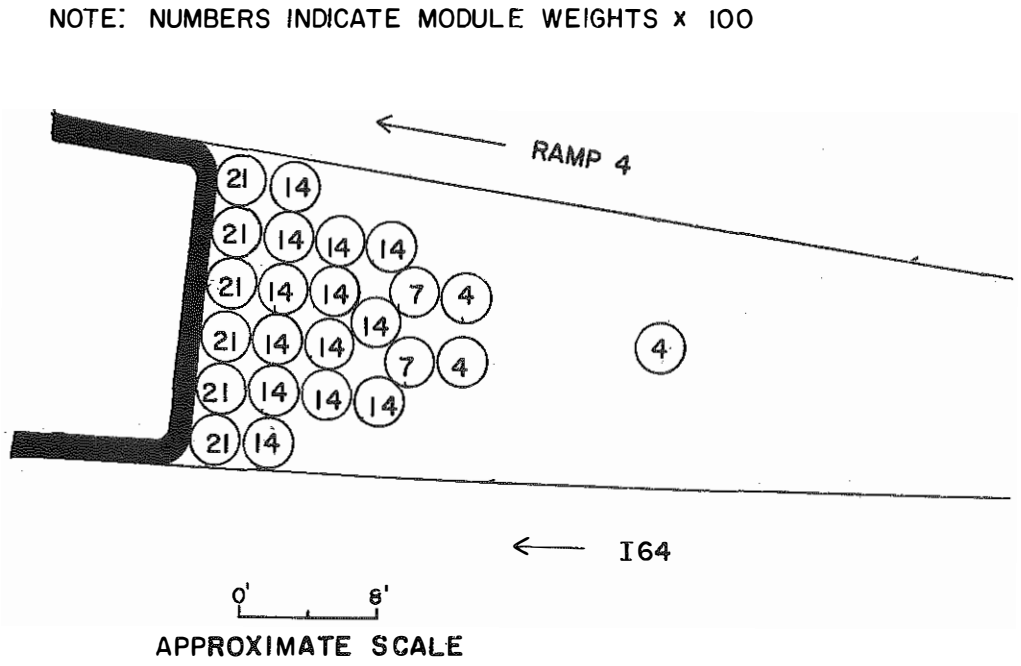


FIGURE 12. Plan View of FITCH System Design for Location 2 (b); Jefferson County, I 64 (Riverside Expressway) - 9th Street Interchange, Gore at Ramp 4

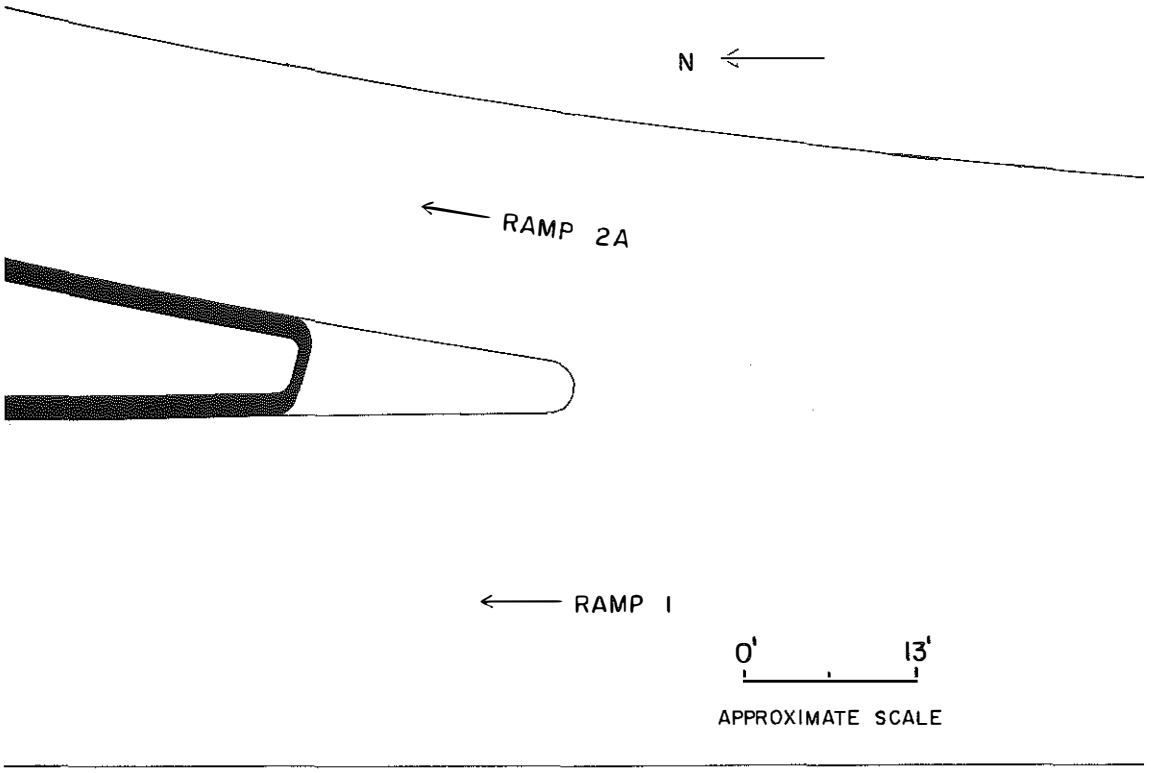


FIGURE 13. Plan View of Location 2 (c); Jefferson County, I 64 (Riverside Expressway) - 9th Street Interchange, Gore between Ramps 1 and 2A

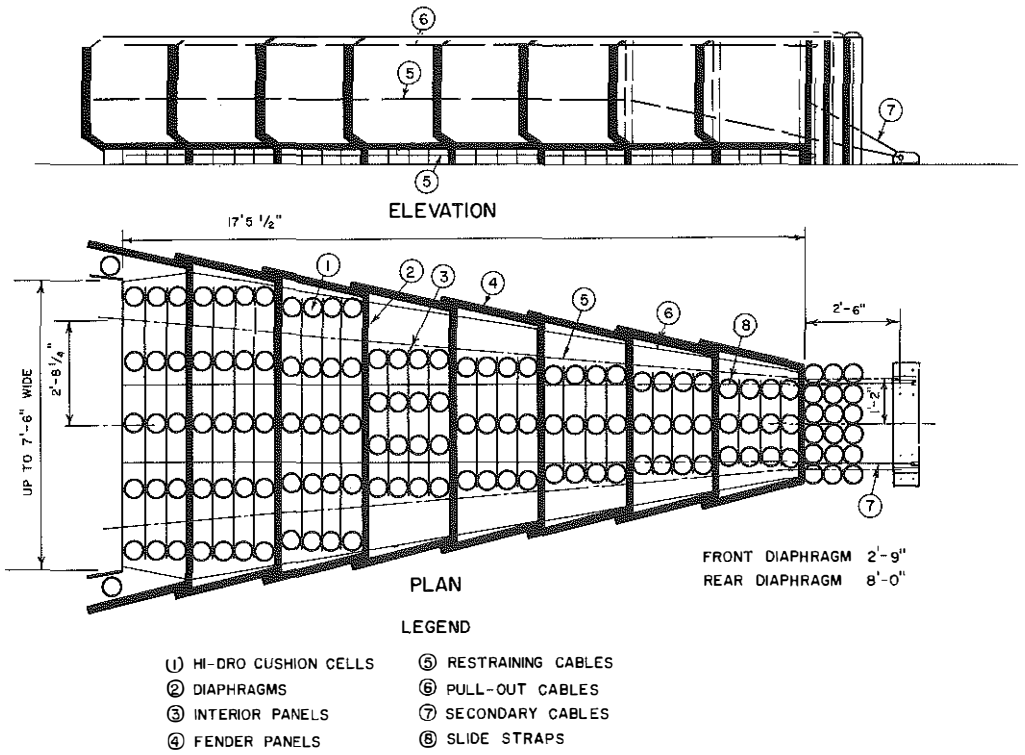


FIGURE 14. HI-DRO CUSHION System Design for Location 2 (c)

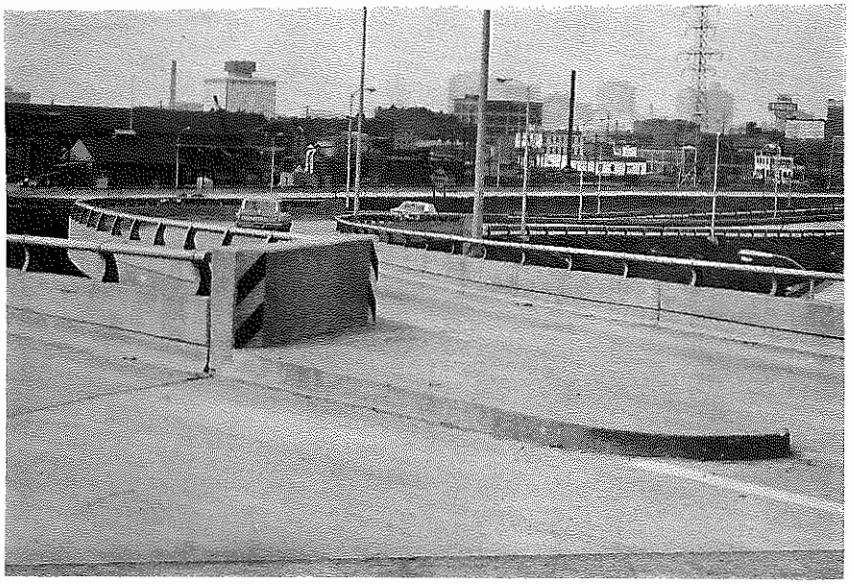


FIGURE 15. Location 3 (a); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Southbound Secondary Gore between Ramps 4 and 8, Prior to Installation of HI-DRO CELL

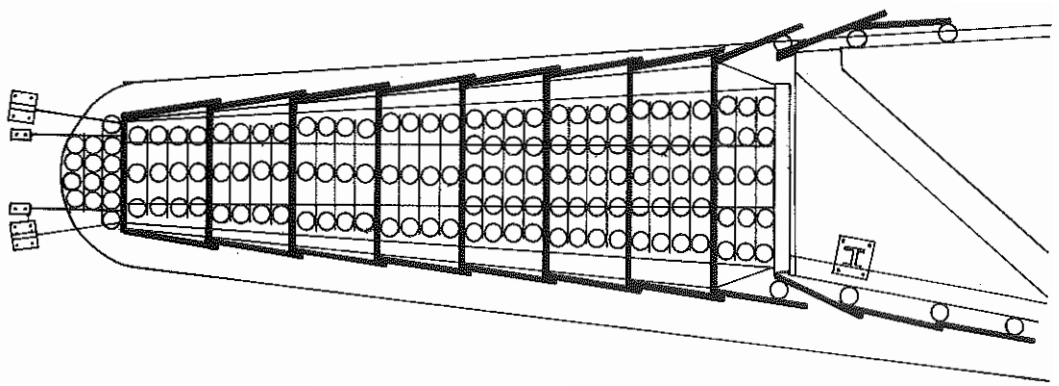


FIGURE 16. HI-DRO CELL Design for Location 3 (a); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Southbound Secondary Gore between Ramps 4 and 8

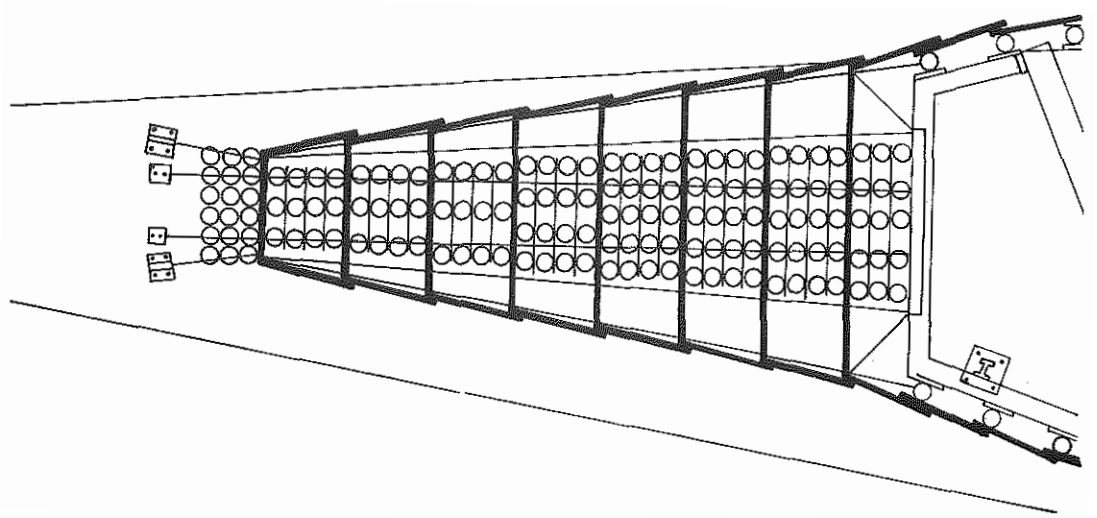


FIGURE 17. HI-DRO CELL Design for Location 3 (h); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Northbound Secondary Gore between Ramps 3 and 6

FIGURE 18. HI-DRO CELL Barrier at Location 3 (a)

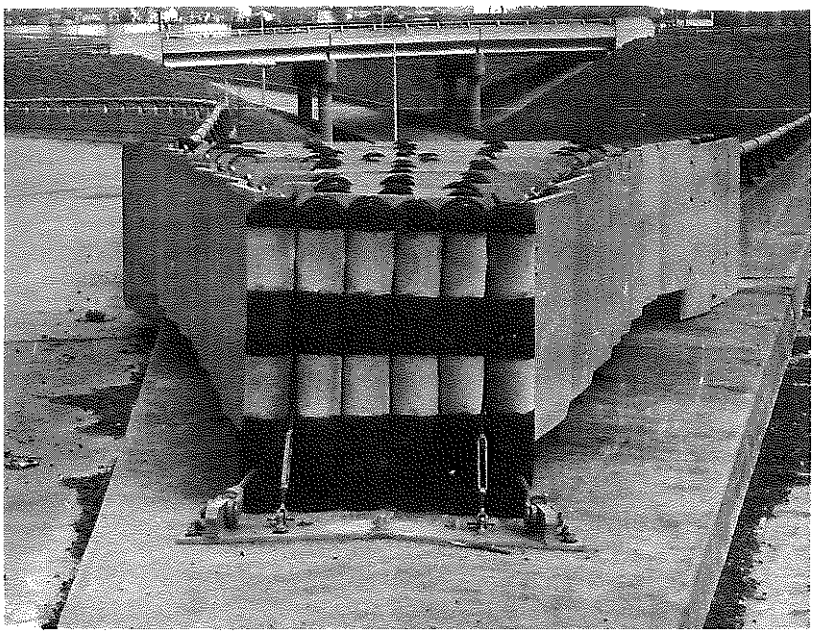


FIGURE 19. HI-DRO CELL Barrier at Location 3 (b)

FIGURE 20. Location 3 (c); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Mainline Exit, Northbound, before Improvements

FIGURE 21. Location 3 (c) after Guardrail Removal and Contour Grading

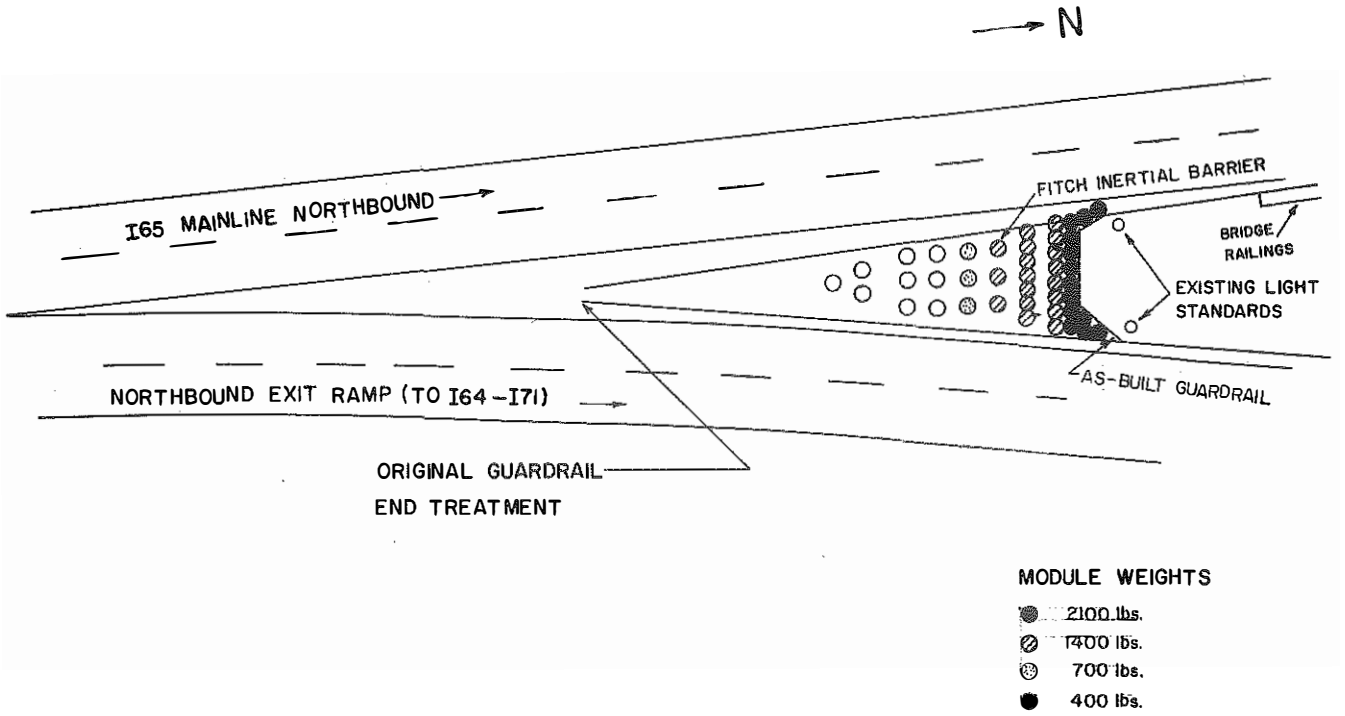


FIGURE 22. Schematic of FITCH Barrier at Location 3 (c)

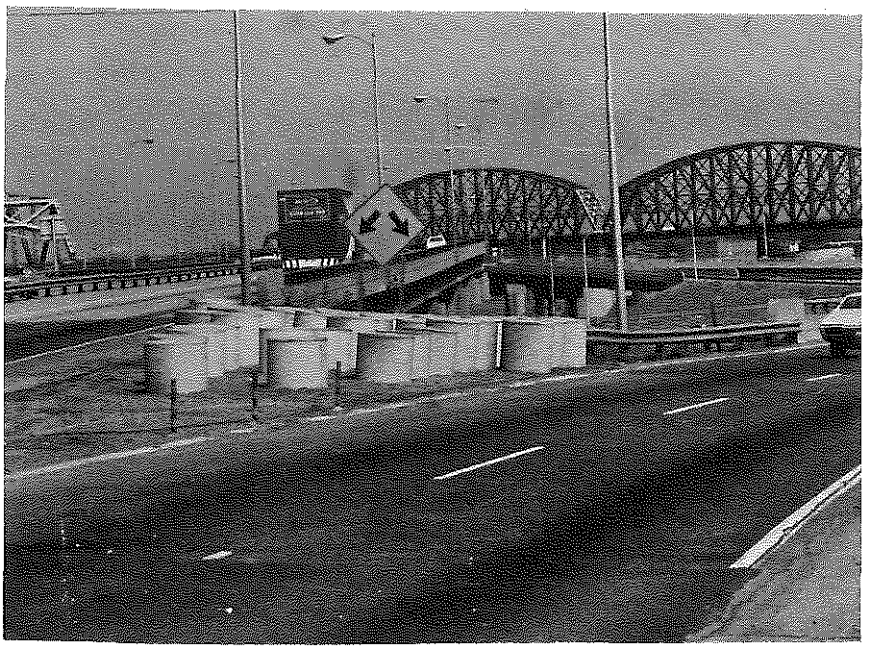


FIGURE 23. FITCH Barrier at Location 3 (c)

Location 3 (d); Jefferson County; Kennedy interchange (I 71 - I 64 - I 65), Mainline exit southbound

This location, pictured in Figure 24, has been designated for a safety barrier and possibly for a camera monitoring system. No other specific plans concerning this site have been formulated at the present time.

Location 4; Kenton County; I 275 - US 25 & US 42 interchange, Gore between Ramps A and C

This gore site is currently under design and is pictured in plan view in Figure 25. It was felt that the conditions at this location, which would make the installation of a safety barrier necessary, could be eliminated through design changes. It was recommended that the portion of the gore on the structure be constructed flush with the structure pavement surface, that the gore area on the fill be contour graded to eliminate precipitous slopes, that the guardrail be eliminated or turned on a large radius, and that installation of an energy absorbing device be deferred. The contour grading and guardrail configuration would be compatible with a future installation.

Location 5; Jefferson County; Jefferson Freeway - Westport Road interchange, Gore at Ramp 5

This gore has just recently been constructed and is only partially in operation; the critical movement is not open to traffic. It was recommended that the gore area be regraded to eliminate the necessity for a safety barrier. The plan view of the gore is shown in Figure 26.

Location 6 (a); Jefferson County; I 264 Shively interchange with US 31W, Gore at Bridge No. 7

The recommendations for this gore are basically the same as those for the I 275 - US 25 and US 42 interchange. This gore is shown in plan view in Figure 27.

Location 6 (h); Jefferson County; I 264 Shively interchange with US 31W, Gore at Ramp 7

Several design modifications were recommended in order to accomodate a barrier. Among the recommendations were: 1) turning the endwalls on a radius and connecting them to close the gap between the structures, 2) utilizing a depressed gore area having minimum cross slopes and a flush drainage box, 3) paving this area with two inches of asphaltic concrete covering a full-depth dense-graded aggregate base, and 4) installing a FITCH barrier in front of the bridge walls. Figure 28 shows the revised plan for this gore.

Location 7; Kenton County; I 75 - Fifth Street interchange, Gore at southbound exit ramp

A FITCH barrier was installed at this location on November 5, 1970. The gore prior thereto is shown in Figure 29. A picture of the system as it presently appears and a schematic plan view are shown in Figures 30 and 31. A camera monitoring system is currently planned for this location.

Location 14; Jefferson County; I 64 - I 264 (New Albany) interchange, Northbound directional split from I 264 to I 64

This site was chosen for installation of a barrier in February 1970. As shown in

FIGURE 24. Location 3 (d); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Mainline Exit, Southbound

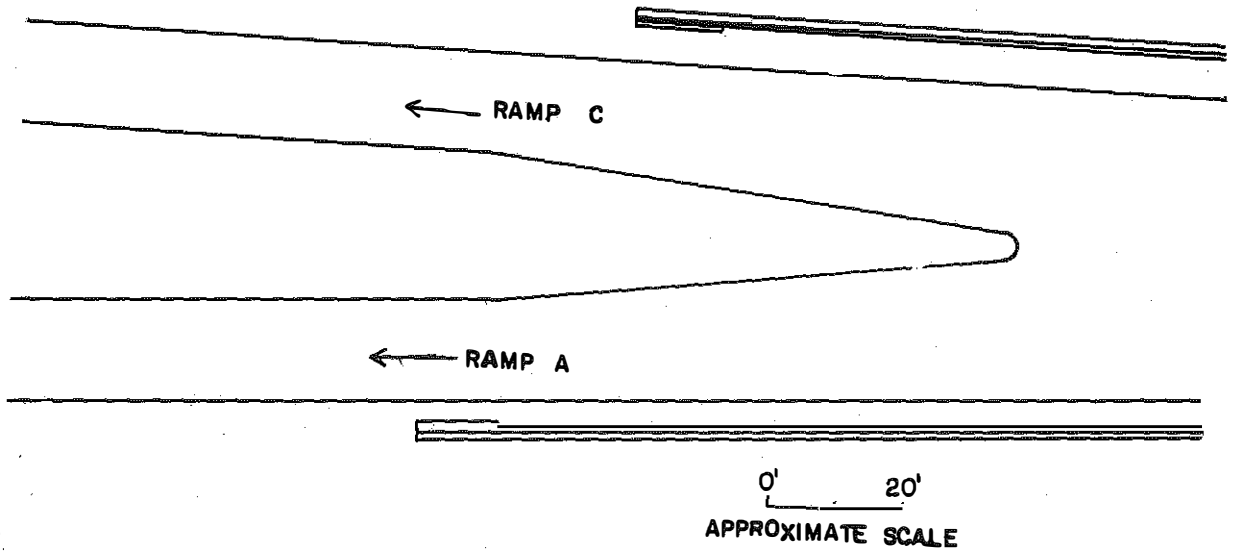


FIGURE 25. Plan View of Location (4); Kenton County, I 275 - US 25 and US 42 Interchange, Gore between Ramps A and C

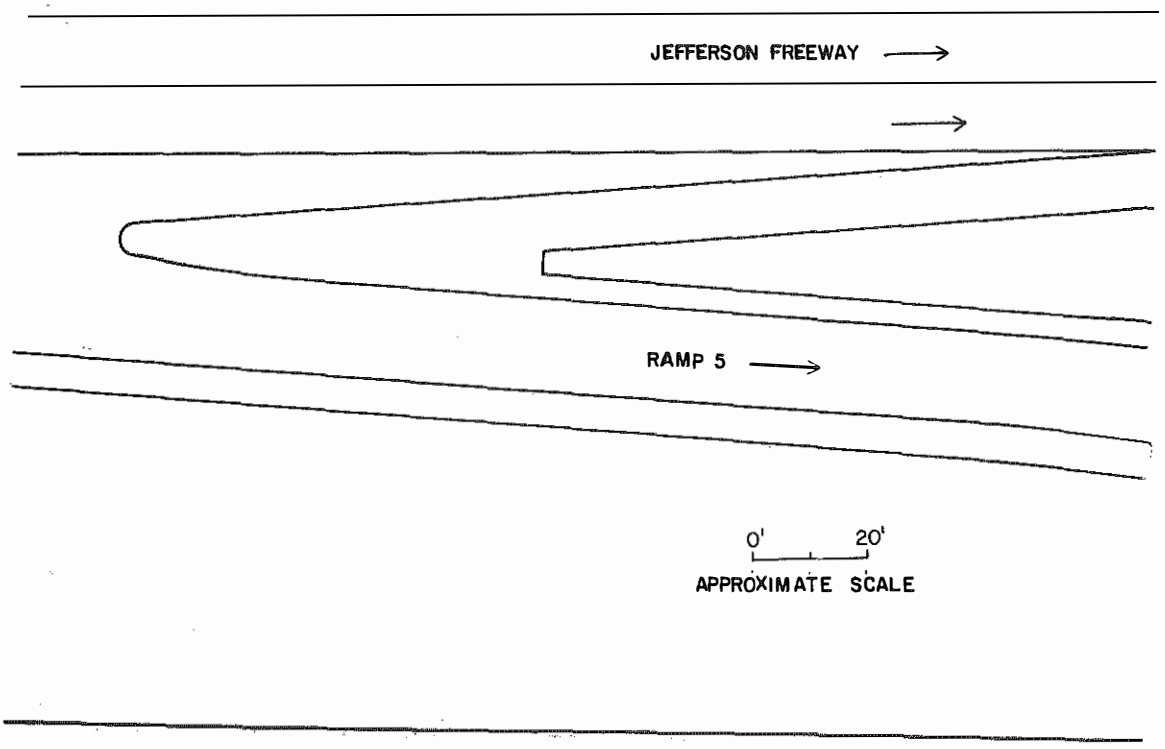


FIGURE 26. Plan View of Location 5; Jefferson County, Jefferson Freeway - Westport Road Interchange, Gore at Ramp 5

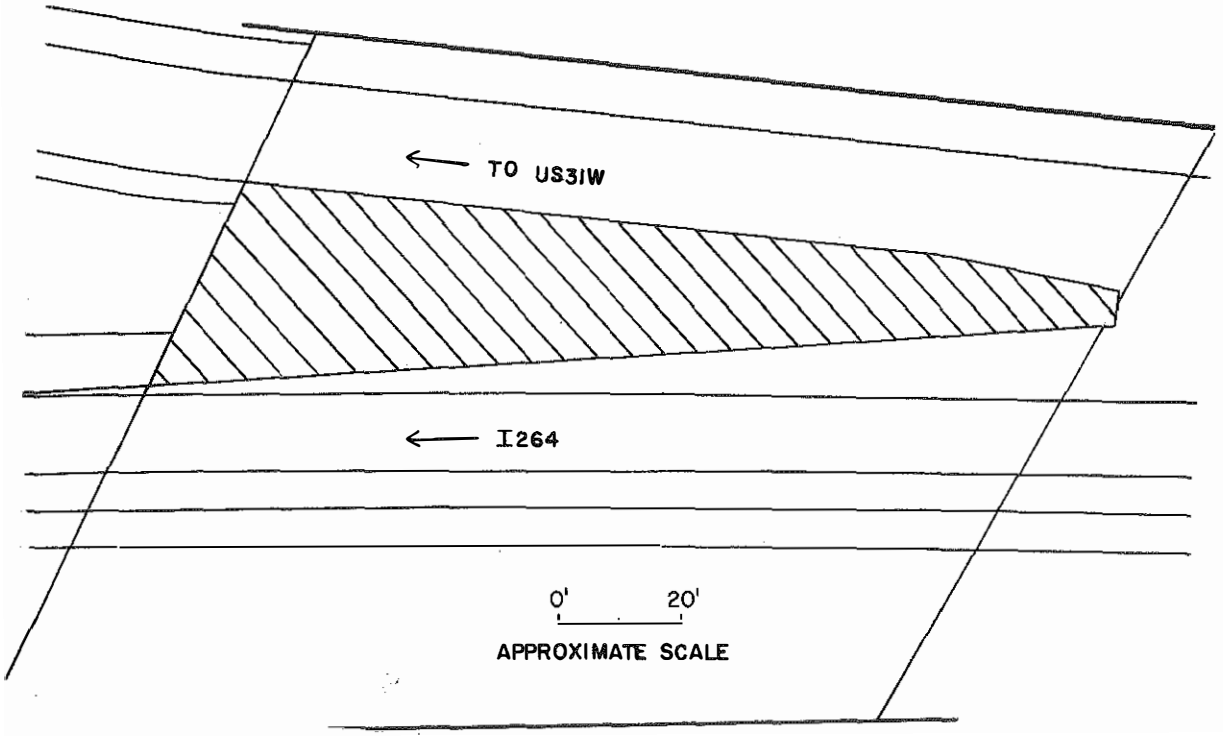


FIGURE 27. Plan View of Location 6 (a); Jefferson County, I 264 Shively Interchange with US 31W, Gore at Bridge No. 7

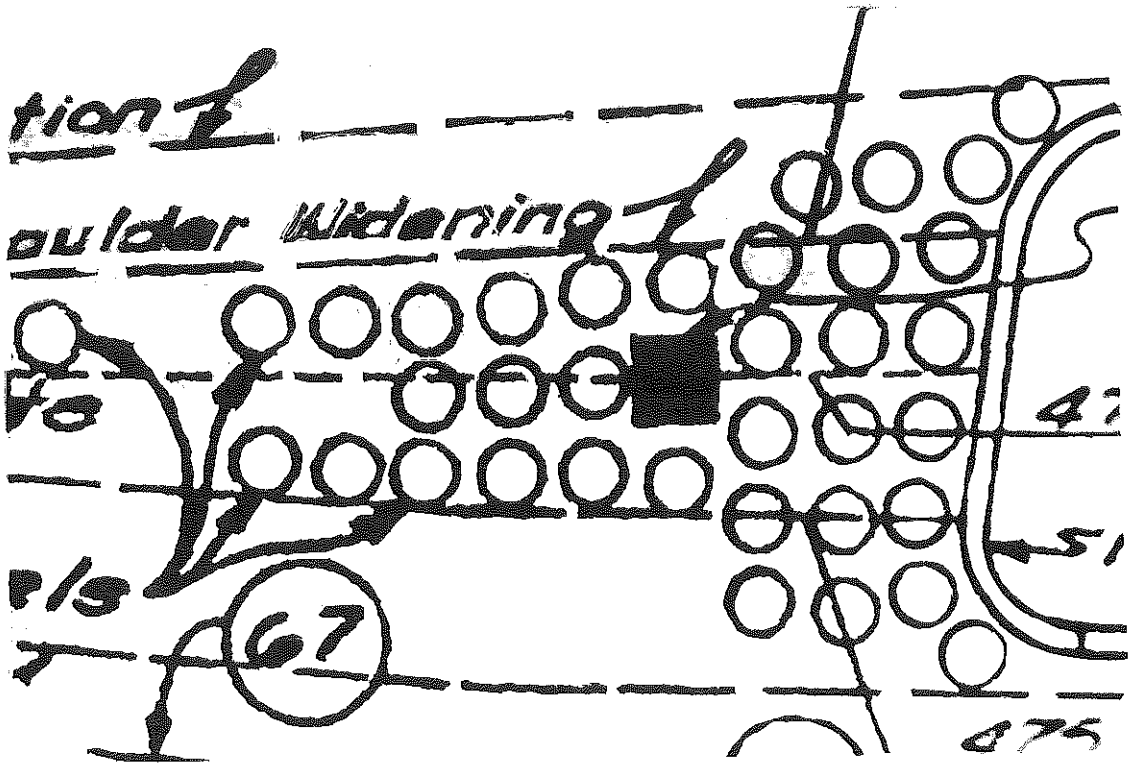


FIGURE 28. FITCH Barrier Designed for Location 6 (b); Jefferson County , I 264 Shively Interchange with US 31 W, Gore at Ramp No. 7

FIGURE 29. Location 7; Kenton County, I 75 - 5th Street Interchange , Gore at Southbound Exit Ramp, before Installation of FITCH Barrier

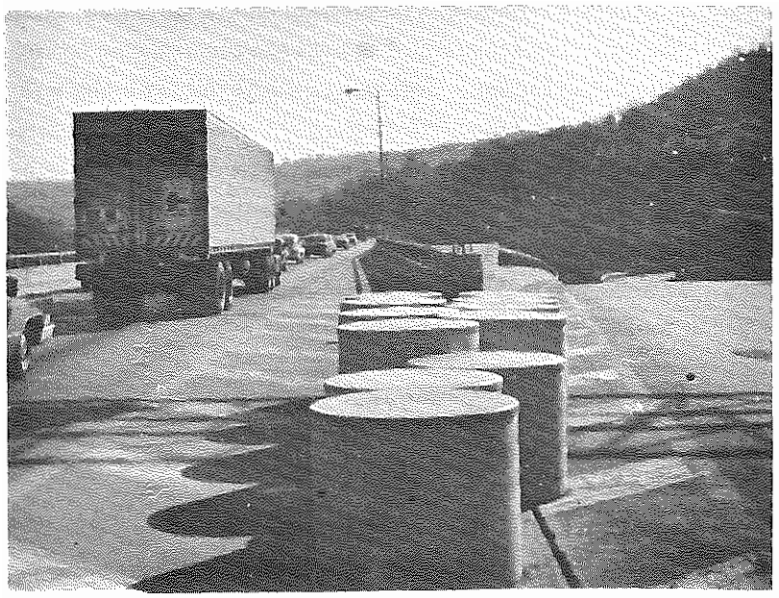


FIGURE 30. Location 7 after Installation of a FITCH Barrier

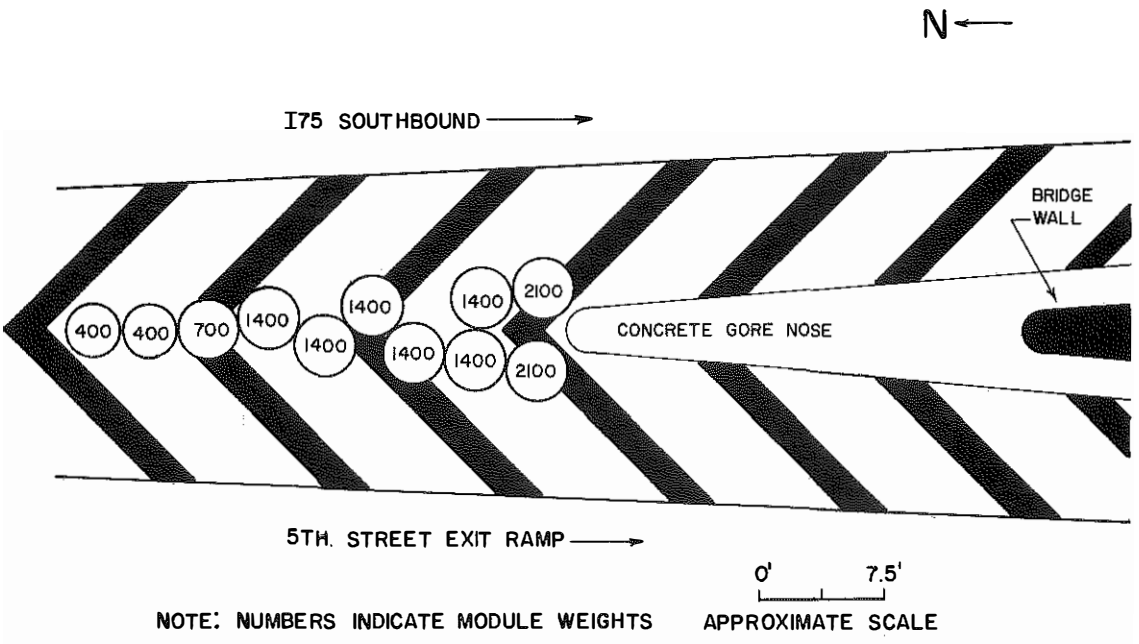


FIGURE 31. Schematic of FITCH Barrier at Location 7

Figure 32, this location is only partially open to traffic. The left-hand ramp leads to I 64, northbound (Riverside Expressway). This gore is unique in that it consists of a concrete nose tapering to a sodded area enclosed by a high curb (11 inches). This triangular gore fronts a bridge wall connecting the adjoining bridge railings. Beyond the bridge wall is a 3:1 slope to a surface street.

After considerable discussion of the possible ramping effects of the tapered (2 inch vertical curb to 11 inch vertical curb, in 25 feet) nose, it was decided that the FITCH barrier array shown in Figure 33 was the optimum design. As an additional anti-ramping safety factor, the 700-pound modules were specified to be 36 inches tall, rather than the normal 30 inches. It is estimated that this barrier will be installed in the second half of 1971.

Location 16; Jefferson County; Riverside Expressway - 22nd Street interchange, Gore at eastbound exit from Riverside Expressway to 22nd Street

This location was selected for installation of an impact attenuating device in September 1970. This section of the Riverside Expressway is currently under construction; it was recommended that the curb designed for this gore area be ramped from pavement grade to full height over a distance of 24 feet. The modification was recommended to accomodate a FITCH barrier system -- shown in plan view in Figure 34.

Location 17; Campbell County; I 471 - I 275 interchange, Gore between I 471 southbound and Ramp F for I 275

The plan view schematic of the FITCH barrier chosen for this bifurcation, which is currently in the design stage, is depicted in Figure 35.

At the other gore locations enumerated above, no additional action has been taken except to delineate some as possible sites for barrier installations. Figures 36 through 44 illustrate each site. It is anticipated that further action will be forthcoming.

ACCIDENTS INVOLVING ENERGY ABSORBING BARRIERS

As of March 1, 1971, four impact attenuating devices had been installed in Kentucky -- two FITCH barriers and two HI-DRO CELL barriers. Since their installation, there have been four accidents involving the FITCH barriers and one involving a HI-DRO CELL barrier.

The first "hit" occurred on January 24, 1971, at 4:05 am at the FITCH barrier on I 75 near Covington. Police were summoned, and an accident report was filed. The driver of the vehicle, a 1964 Chevrolet, stated that he fell asleep and impacted almost head-on but off-center of his vehicle. The impact slowed the vehicle considerably and the driver was able to stop his car as it veered down the exit ramp. The driver estimated his speed to be 40-45 mph, and Research personnel estimated his angle of impact to be 13 degrees. Extent of damage to the vehicle is uncertain since the driver planned to repair the car himself; he estimated the cost of

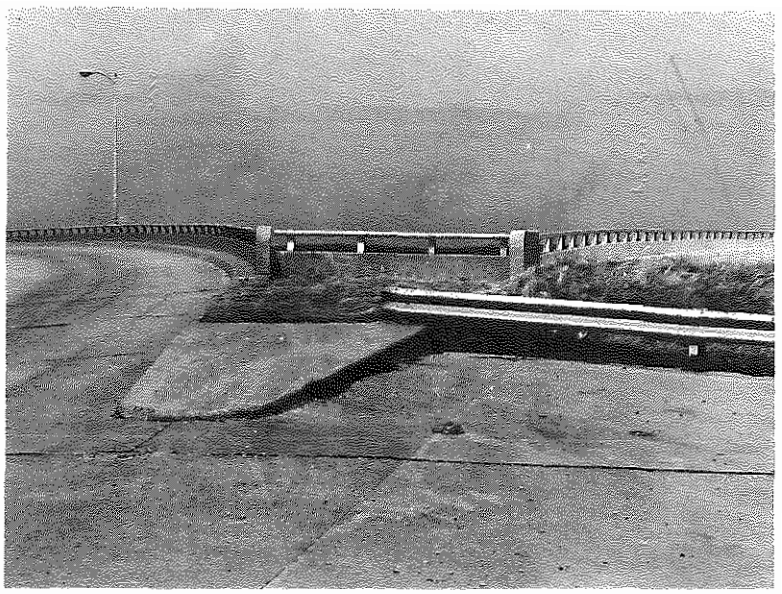


FIGURE 32. Location 14; Jefferson County, I 64 - I 264 (New Alhany) Interchange, Northhound Directional Split from I 264 to I 64.

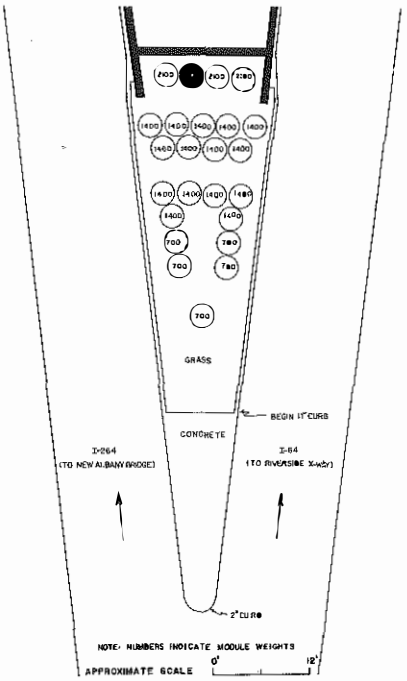


FIGURE 33. Schematic of FITCH Barrier Designed for Location 14

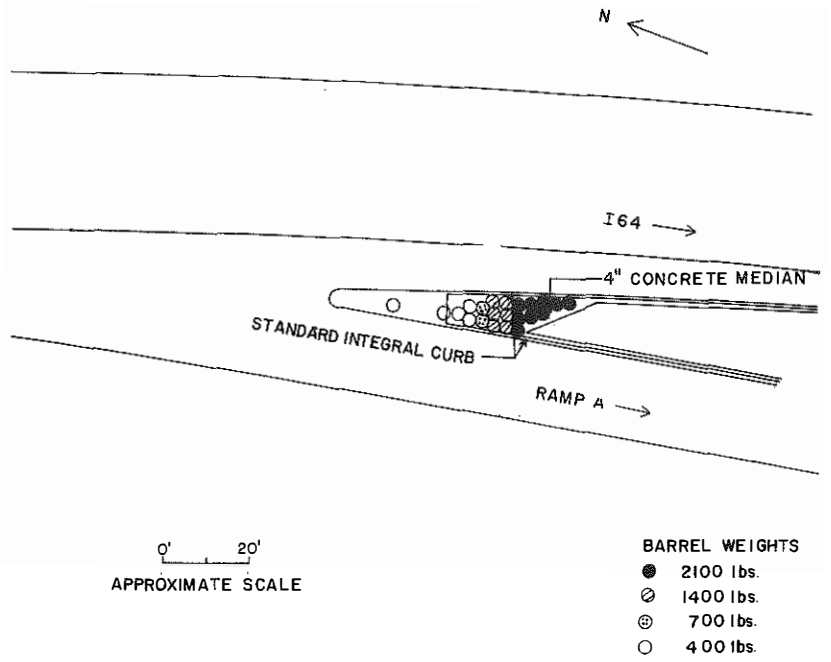


FIGURE 34. Schematic of FITCH Barrier Designed for Location 16; Jefferson County, Riverside Expressway - 22nd Street Interchange, Gore at Eastbound Exit from Riverside Expressway to 22nd Street

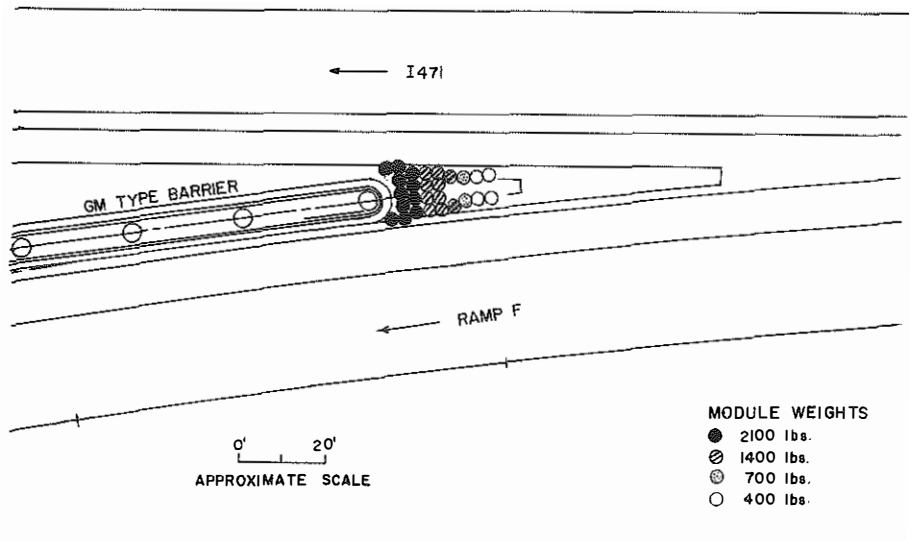


FIGURE 35. Schematic of FITCH Barrier Designed for Location 17; Campbell County, I 471 - I 275 Interchange, Gore between I 471, Southbound, and Ramp F on I 275

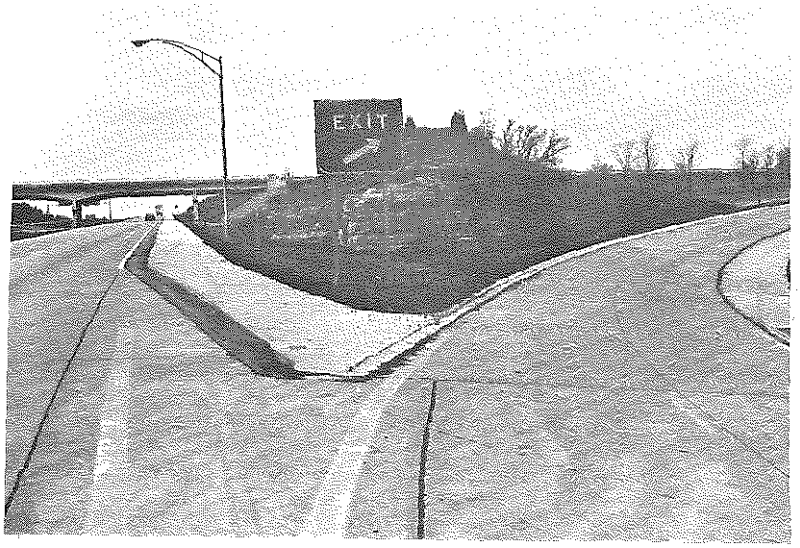


FIGURE 36. Location 8 (a); Franklin County, I 64 - US 127 Interchange, Gore at Westbound Exit from I 64 to US 127

FIGURE 37. Location 8 (b); Franklin County, I 64 - US 127 Interchange, Gore at Eastbound Exit from I 64 to US 127

FIGURE 38. Location 9; Shelby County, I 64 - KY 395 Interchange, Gore at Eastbound Exit from I 64 to KY 395

FIGURE 39. Location 10; Fayette County, I 75 - US 25 and US 421 Interchange, Gore at Northbound Exit from I 75 to US 25 and US 421

FIGURE 40. Location 11 (a). Whitley County, I 75 - US 25 Interchange, Gore at Southbound Exit from I 75 to US 25

FIGURE 41. Location 11 (b); Whitley County, I 75 - US 25 Interchange, Gore at Northbound Exit from I 75 to US 25

FIGURE 42. Location 12; Jefferson County, I 65 - Chestnut Street Interchange, Gore at Northbound Exit from I 65 to Chestnut Street

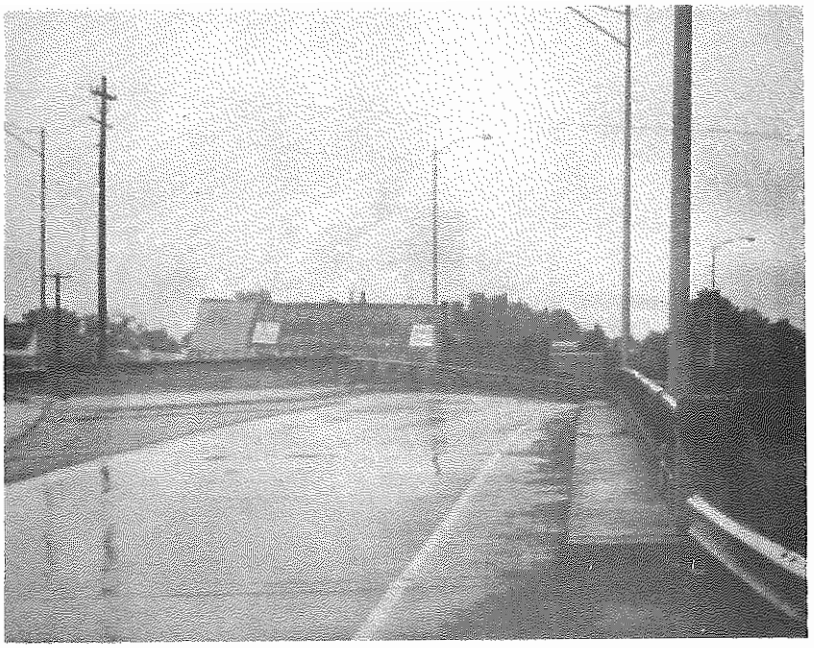


FIGURE 43. Location 13; Jefferson County, I 65 - St. Catherine Street Interchange, Gore at Southbound Exit from I 65 to St. Catherine Street

FIGURE 44. Location 15; Jefferson County, I 64 - 3rd Street Interchange, Gore at Westbound Exit from I 64 to 3rd Street

parts to be a little over 100 dollars.

Of the eleven modules in this modified 6 x 21 barrier, eight were destroyed (Figure 45). However, had the barrier not been installed, the errant vehicle surely would have hit the concrete wall. For this reason, police on the scene credited the barrier with possibly saving the life of or preventing injury to the driver. The driver concurred inasmuch as he was uninjured.

The second hit occurred at the FITCH barrier in Louisville on or about February 11, 1971. Since the driver was able to travel on, there was no police report and no record of the accident. Eight modules were destroyed, and two more were overturned but reusable. The damage done to the barrier is shown in Figure 46. The angle of impact was estimated to be ten degrees. From tire marks in the gore leading to the barrels, it appeared that the vehicle might have struck the bridge wall had the barrier not been installed.

The third hit (the second hit at this site) occurred at the FITCH barrier on I 75 near Covington on February 15, 1971. Only the two front modules were destroyed in this drive-away situation; circumstances contributing to the accident are unknown (Figure 47).

The fourth hit occurred at the FITCH barrier at the Kennedy Interchange (the second hit at this site also) in Louisville on or about February 17, 1971. Two flanking modules to the rear and adjacent to the mainline flow of traffic (I 65N) were shattered -- evidently by a side-swiping hit (Figure 48). Again, the driver and vehicle vanished and no police report was made.

The fifth and final hit to date was a minor impact of the HI-DRO CELL barrier at the southbound secondary exit at the Kennedy Interchange, Location 3 (a). This accident, the circumstances of which are not known, occurred sometime in February 1971. It can be seen from Figure 49 that one shear pin was broken and that the tension in some of the cables was relaxed; also, the front of the barrier appears to have been knocked slightly out of alignment.

In summary, of the five accidents thus far, four have evidently been drive-away situations. Thus, vehicle damage appears to have been minimized; one life was possibly saved, and what could have been serious injury accidents were evidently avoided.

CURRENT STATUS OF VISUAL RECORDING SYSTEM

In February 1971, eight gun-sight movie cameras, similar to the one presently in use in Louisville, were acquired. Since the camera presently in use would not take viewable footage under nighttime conditions, plans are being made to install two cameras at a barrier site. One camera would be loaded with a daylight-type film, and the other with a suitable high-speed night film. It is hoped that film footage of acceptable quality can be obtained.

An actual accident has yet to be filmed at a barrier site. The first accident at the site being monitored, Location 3 (c), was not filmed because all the film in the camera had been exposed prior to the accident. This was due to inclement weather which had forced a delay in the regularly scheduled changing of the film. When the second accident occurred, the system was

FIGURE 45. Location 7; Kenton County, I 75 - 5th Street Interchange, Gore at Southbound Exit Ramp after First "Hit"

FIGURE 46. Location 3 (c); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Mainline Exit Northbound after First "Hit"

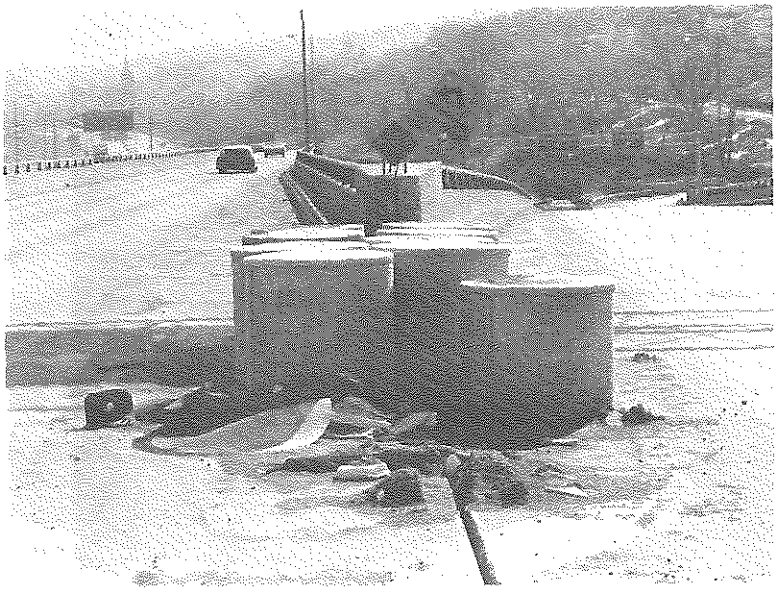


FIGURE 47. Location 7 after Second "Hit"

FIGURE 48. Location 3 (c) after Second "Hit"

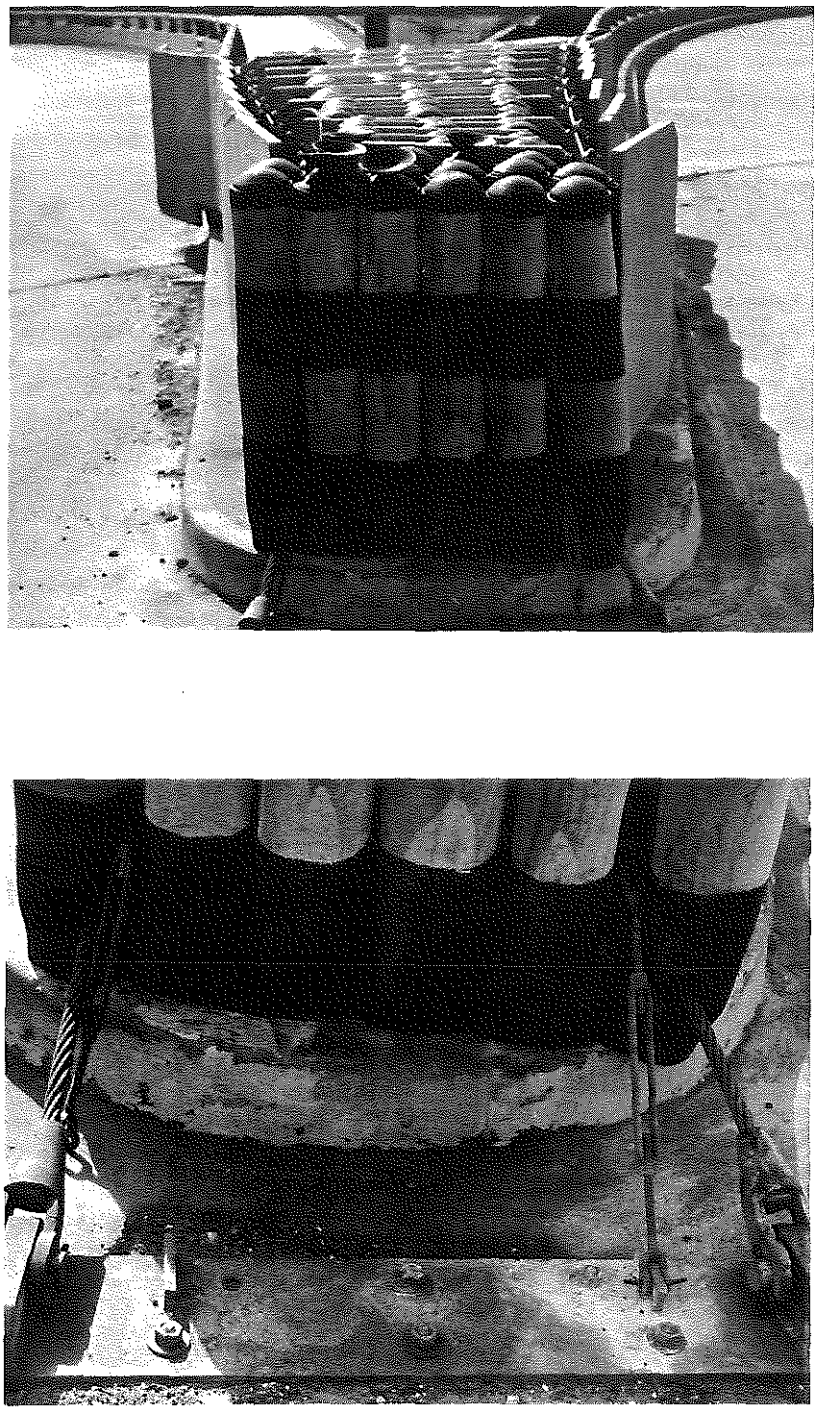


FIGURE 49. Location 3 (a); Jefferson County, Kennedy Interchange (I 71 - I 64 - I 65), Southbound Secondary Gore between Ramps 4 and 8 after First "Hit"

not functioning properly. Other sites where accidents occurred were not being monitored.

With the newly acquired cameras, four sites will be monitored, and a better servicing schedule will be maintained. A closed-loop, self-erasing video tape system is still under consideration, but the camera systems now being employed suffice nicely. Films already obtained illustrate a surprising level of activity in the gore being monitored.

CONTINUATION

Accident data will be collected for the gore locations prior to and after the installation of a barrier. Particular emphasis will be placed on the effectiveness of the barrier types. This will also apply to locations in the design stage at which a barrier installation is not imminent. In addition, the locations under design at which it was recommended that gore regrading with gently sloping contours be employed instead of a safety barrier will be monitored following construction for accident styles to ascertain if this recommendation was sufficient or if further safety measures appear to be warranted. Finally, constant vigilance will be maintained over the state's highway system to identify any additional locations at which the installation of this type of device could be employed to reduce the frequency and severity of accident occurrence.

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2. Garner, G. R. and Venable, J. B., "A Preliminary Evaluation of Mounds to Divert Wayward Vehicles Away from Rigid Obstructions", Kentucky Department of Highways, Division of Research, August 1969.

3. Garner, G. R., "Accidents at Median Crossovers", Kentucky Department of Highways, Division of Research, June 1969.

4. Garner, G. R., "Median Design and Accident Histories", Kentucky Department of Highways, Division of Research, April 1970.

5. Venable, J. B., "Impact Energy Absorption Barriers", Kentucky Department of Highways, Division of Research, September 1969.

6. "Rich's Hi-Dro Cushion Cells - Street and Highway Applications", John Rich Enterprises, Inc., Sacremento, California, 1969.

7. "Fitch Inertial Barrier System for Highway Safety", FIBCO, Inc., Hartford, Connecticut, 1969.

8. "An Energy Absorbing Reusable Highway Protective System", Report No. 86, Aerospace Research Associates, June 1967.

9. Hirsch, T. J., "Tor-Shock Energy Absorbing Protective Barrier", Technical Memorandum 505-2 , Texas Transportation Institute, July 1968.

10. Gregory, R. T., "Visual Recording Systems for Field Installations of Energy Absorbing Systems", Technical Memorandum No. 619-1, Texas Transportation Institute, January 1970.

11. AASHO Special Traffic Safety Committee, "Highway Design and Operational Practices Related to Highway Safety", AASHO, February 1967.

12. "Hi-Dro Cushion Cell Sandwich Units", Energy Absorption Systems, Inc., Sacremento, California, 1970.

13. "Fitch Inertial Barrier System Design Manual", FIBCO Inc., Hartford, Connecticut, 1970.

14. Kudzia, W. J., "The Fitch Inertial Barrier and Its Performance in Connecticut", Connecticut Department of Highways, September 1970.

15. Darrell, J. E. P. and Dunnette, M. D., "Driver Performance Related to Interchange Marking and Nighttime Visibility Conditions", Bulletin 255, Highway Research Board, July 1960.

16. Hirsch, T. J., "The Modular Crash Cushion", Technical Memorandum No. 505-15, Texas Transportation Institute, August 1970.

5. Tamanini, F. J. and Viner, John G., "Structural Systems in Support of Highway Safety", paper presented ASCE National Meeting on Transportation Engineering, July 1969.

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7. Hirsch, T. J. and Ivey, Don L., "Vehicular Impact Attenuation by Modular Crash Cushion", Texas Transportation Institute - Texas Highway Department Cooperative Research Report 146-1.

8. Hirsch, T. J., "Barrel Protective Barrier", Texas Transportation Institute Technical Memorandum 505-1, July 1968.

9. "Rich's Hi-Dro Cushion Cells - Street and Highway Applications", John Rich Enterprises, Inc., Sacremento, California, 1969.

IV. OBJECTIVES OF THE STUDY

The purpose of this project is to ascertain the effectiveness of impact attenuation devices in gore areas of structures as related to their safety value and maintenance requirements.

V. IMPLEMENTATION

A survey has been completed of all exit ramp gores on interstate facilities in the state, including those locations presently in operation and those being designed, to inventory deficiencies. A general outlook was incorporated into the survey, allowing recommendations for corrective measures other than safety barriers where appropriate. For example, several gore areas under design which were deficient from the point of safety were corrected by specifying contour grading within the gore area to provide a safe emergency path of travel for an errant vehicle. In addition, minor regrading would correct deficiencies at many existing locations.

There were approximately 20 sites (existing and those in the design stages) at which the installation of safety barriers were deemed appropriate. This total does not include an equal number of locations on one section of interstate roadway which is to be corrected with a programmed safety project. These gore areas have been analyzed, and the most appropriate safety barrier for each location was selected. A listing of sites at which impact attenuating barriers are to be installed is attached.

Two types of safety barriers chosen for experimental installation in Kentucky are the HI-DRO CUSHION CELLS and the FITCH INERTIAL BARRIER. These two types of devices have

been shown to perform adequately under field conditions. Other types of devices were considered but were judged to be relatively untested and in need of extensive modifications. If at such time these devices are judged to be effective relative to the criteria imposed, then their installation will be considered as need arises for additional gore protection.

As part of the monitoring process, vehicle-actuated cameras will be installed at several locations. The cameras will be located so that the range of visual recording will include the gore area and the approach and so provide a working knowledge of the vehicular path prior to intrusion in the gore area. It is proposed to install an actuating device, such as pneumatic tube, which will eliminate the necessity for continuous filming and will, instead, record only that activity relative to the study.

VI. BENEFITS

The benefits to be derived from this study cannot totally be measured on an economic scale. Every traffic accident entails a certain monetary loss which is the result of reparation. However, economic bases are poor criteria for judging permanent or temporary loss of human resources. A glance at the accident histories of four existing gore locations where impact attenuating devices are to be installed is indicative of the savings (in terms of money and human resources) to be derived from this study:

Location	Length of Accident History	No. of Accidents	Injuries	Fatalities
1	18 months	2	1	0
2	18 months	0	0	0
3	18 months	9	6	2
4	11 months	6		0

VII. WORK PLAN

Monitoring of selected installations will be conducted by means of vehicle-actuated camera devices to record the impact. In addition, maintenance personnel will be requested to obtain photographs of the barriers prior to repairs of damage caused by a vehicle collision. Cooperation will be solicited from local law enforcement officials who investigate accidents involving safety barriers. Traffic accident histories before and after barrier installation will be compiled and evaluated.

VIII. STAFFING PLAN

Research Engineers (2)	25%
Engineering Aide (electronics technician)	20%
Engineering Aides (2)	10%

IX. LEVEL OF EFFORT

It is anticipated that each gore location will be monitored for 12 months after installation. Some installations in the design stage will not be in operation until 24 months hence. Therefore, it is anticipated that 36 months will be required to successfully complete the program described herein. Interim progress reports will be prepared at the end of twelve and twenty-four months.

Occasionally, it may be necessary to deploy personnel to other studies in order to meet requirements of the Department or take advantage of timely opportunities to advance other studies. This may result in delays in the execution of portions of this study and thus extend the time for completion.

X. FACILITIES AVAILABLE

The Division of Research is housed in a large, new laboratory and office building designed to accommodate personnel and equipment. An electronics workshop is available for maintenance and repairs of the instrumentation and equipment required in the study. The Division of Research is well equipped with calculators and other office and reproduction equipement. The University of Kentucky's IBM 365 computer and consultation services are also available.

XI. SUPPORTING DATA

The following studies in the general area of traffic and safety have been conducted by the Kentucky Department of Highways:

1. Deacon, J.A. and Lynch, R.L., "Determination of Traffic Parameters for Prediction, Projection, and Computation of EWL's", Kentucky Department of Highways, Division of Research, 1968.

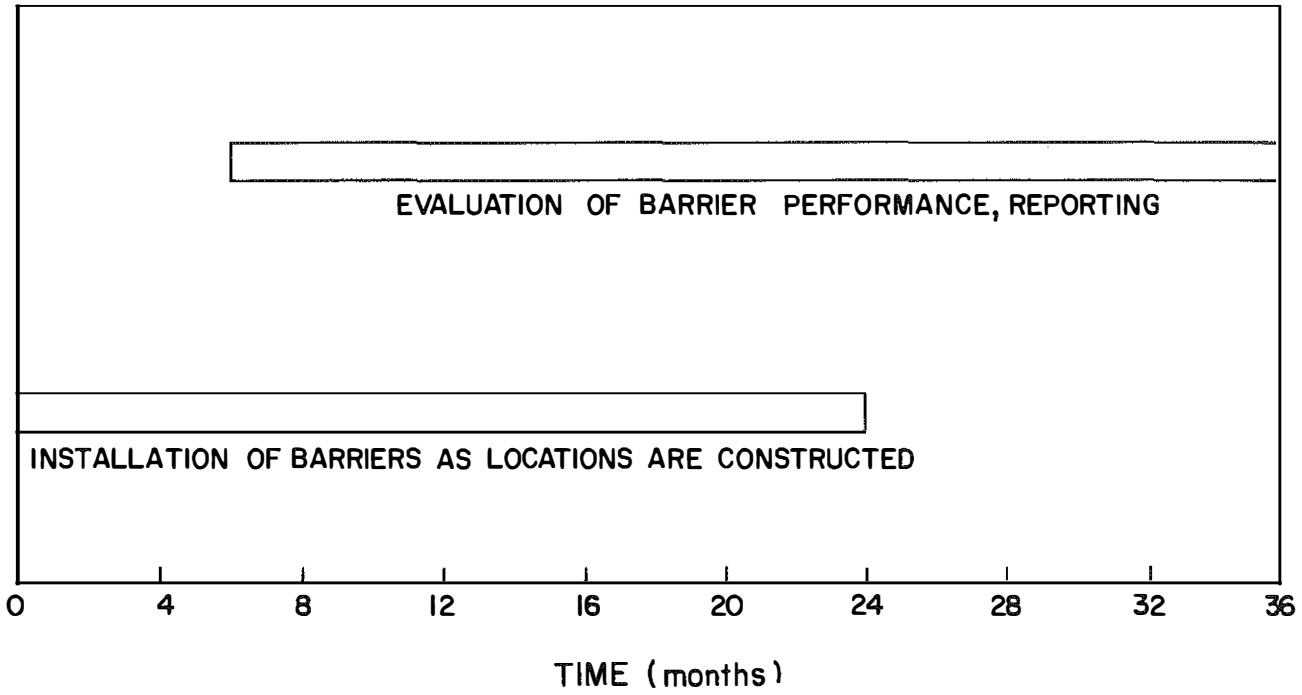
2. Lynch, R.L., "Analysis of Traffic Loads on Bridges", Kentucky Department of Highways, Division of Research, 1968.

3. Lynch, R.L. and Hamby, G.N., "Lateral Distribution of Traffic on a Four-Lane and Six-Lane Section of I 75 South of Covington", Kentucky Department of Highways, Division of Research, 1969.

4. Garner, G.R., "Accidents at Median Crossovers", Kentucky Department of Highways, Division of Research, 1969.

5. Garner, G.R., and Venable J. B., "A Preliminary Evaluation of Mounds to Divert Wayward Vehicles Away from Rigid Obstructions", Kentucky Department of Highways, Division of Research, 1969.

XII. WORK TIME SCHEDULE



XIII. BUDGET ESTIMATE

	Total	FY 1971	FY 1972	FY 1973
1. Personnel	$21,000	$ 7,000	$7,000	$7,000
2. Non-Expendable Equipment				
Cameras and associated items	5,500	5,500	0	0
3. Consumable Supplies	600	200	200	200
4. Travel and Subsistance	1,500	500	500	500
5. Computer Time	300	100	100	100
TOTAL	$28,900	$ 13,300	$7,800	$7,800

SITES FOR IMPACT ATTENUATING BARRIER INSTALLATION

(* Existing Site)

(**Partially Open to Traffic)

1. I 64 - US 127 Interchange; Franklin Co.; Westbound Exit Gore from I 64 to US 127; MP 53.9.*
2. I 64 - KY 395 Interchange; Shelby Co.; Eastbound Exit Gore from I 64 to KY 395; MP 43.2.*
3. I 64 - US 127 Interchange; Franklin Co.; Eastbound Exit Gore from I 64 to US 127; MP 53.6.*
4. I 75 - US 25 & 421 Interchange; Fayette Co.; Northbound Exit Gore from I 75 to US 25-421; MP 97.9.*
5. I 75 - US 25 Interchange; Whitley Co.; Southbound Exit Gore from I 75 to US 25; MP 14.0.*
6. I 75 - US 25 Interchange; Whitley Co.; Northbound Exit Gore from I 75 to US 25; MP 13.8.*
7. I 264 - I 64 Interchange; Jefferson Co.; Northbound Exit Gore (I 64 North to the Left, I 64 South to the Right)**
8. I 65 - I 71 Interchange (Kennedy Interchange; Jefferson Co.; Mainline Exit Southbound.*
9. I 64 - 3rd Street Interchange; Jefferson Co.; Westbound Exit Gore from I 64 to 3rd Street.**
10. I 65 - Chestnut Street Interchange; Jefferson Co.; Northbound Exit Gore.*
11. I 65 - St. Catherine Interchange; Jefferson Co.; Southbound Exit Gore.*
12. I 264 - US 31W Interchange; Jefferson Co.; Gore between Mainline Westbound and Ramp No. 7.
13. 9th Street - I 64 Interchange where Ramp 3 Exits I 64 Eastbound.
14. 9th Street - I 64 Interchange where Ramp 4 Exits I 64 Westbound.
15. I 275 - Ramps A and C over US 25 - 42.
16. Campbell County; I 471 at Ramp L.
17. Shively Interchange; Bridge No. 7, I 264 Eastbound over US 31W.

18. Jefferson Freeway over Westport Road.

19. Kennedy Interchange; Jefferson County on I 65 in the Gore between Ramps 4 and 8.*

20. Kennedy Interchange in the Gore between Ramps 3 and 6.*

21. Kennedy Interchange in the Gore of Mainline Exit Northbound.*

22. Kenton County, I 75, Southbound Exit to 5th Street.*

APPENDIX C

SPECIAL PROVISION NO. 86 - A
FITCH - TYPE ENERGY ABSORBING BARRIER SYSTEM

PROPOSED SPECIAL PROVISION
HI - DRO CUSHION - TYPE ENERGY ABSORBING BARRIER SYSTEM

KENTUCKY DEPARTMENT OF HIGHWAYS
(Experimental)
SPECIAL PROVISION NO. 86-A

FITCH-TYPE ENERGY ABSORBING BARRIER SYSTEM

This Special Provision shall be applicable when indicated in the plans or proposal.

I. DESCRIPTION

This energy absorbing barrier system shall be as developed by the Fitch Inertial Barrier Company (FIBCO), Inc., of Hartford, Connecticut, and/or Douglastown, New York, and shall be installed in accordance with the manufacturer's instructions, except as otherwise provided herein, at sites designated in the plans.

II. MATERIALS

The materials for the installed barrier system shall consist of (1) individual barrier elements and (2) sand-salt mixture. Materials to be supplied for future use by the Department's forces for replacement of damaged barriers shall consist of individual barrier elements only.

A. Elements. The individual barrier elements shall consist of modules and other necessary parts as manufactured by FIBCO, Inc., and shall be of the appropriate height and diameter to be compatible with the weight of the sand-salt mixture to be placed therein. The color of the modules and lids shall be federal yellow. Each module shall be furnished complete with all component parts such as lid, seal, disc, core, and bottom disc.

B. Sand-Salt Mixture. The mixture to be placed in the modules shall consist of 95% of air-dried natural sand conforming to the requirements of Article 611.6.2 of the Department's 1965 Standard Specifications and of 5% of commercial quality salt which has been thoroughly mixed with the sand so as to intersperse the salt throughout the mixture.

III. CONSTRUCTION METHODS

The individual elements of the barrier system shall be located at the sites depicted in the plans.

When the barrier system is placed on cement concrete or bituminous concrete surfaces, the location of each module of the barrier system shall be painted with a 36 inch outside diameter circle. The width of the line forming the circle shall be inches. Inside the circle, the number of each module shall be painted in numerals 12 inches all in accordance with the schematic shown in the plans. The width of the lines for the numerals shall be 2 to 3 inches. Yellow paint shall be used both for the circle and the numerals.

When the barrier system is placed on dense-graded aggregate, earth, or other surface unsuitable for painting, the location of each module shall be marked by a 12-inch square piece of 12-gage galvanized sheet metal held in place by a 1/2-inch diameter steel pin at least 12 inches long which has been driven into the surface. The pin shall be driven through a preformed hole in the center of each piece of sheet metal and shall have a head of sufficient size for driving and for securely holding the piece of sheet metal in place. Yellow numerals 6 inches tall indicating the number designation of each module, in accordance with the schematic shown in the plans, shall be painted on the pieces of sheet metal.

After the sites have been marked as described above, the individual elements shall be installed and shall be filled, in place, with the correct quantity of the sand-salt mixture. The mixture shall be placed in the quantity specified for each individual module as shown in the plans, and shall be placed in the upper part of the module by utilizing the seal, disc, core, and bottom disc for support. The lids shall be snapped shut on the modules after the mixture has been placed. The lids shall then be drilled at 4 equidistant points and riveted in place. All excess or spilled mixture shall be cleaned up and removed from the site after the modules have been filled.

The plans will also designate the number and size of the individual barrier elements for a site that are to be furnished and delivered to the departmental storage area designated by the Engineer, so the Department's maintenance forces may have a readily available supply of elements for replacement purposes.

IV. MEASUREMENT AND PAYMENT

The completed installation of a barrier system at a site will be measured in a lump sum. Payment for the completed installation will be at the contract lump sum price, which price shall constitute full payment for furnishing, hauling, and installing all the individual elements and sand-salt mixture necessary for a complete installation and for furnishing all labor, equipment, tools, and incidentals that may be necessary to satisfactorily complete the installation.

The total number of individual elements for a site of the sizes specified in the plans for future use by the Department's forces for replacement purposes will be measured as a lump sum. Payment for the replacement elements at the contract lump sum price will constitute full payment for furnishing and delivering to the departmental storage area all of the replacement elements designated in the plans for a site.

APPROVED October 19, 1970

A. O. NEISER
STATE HIGHWAY ENGINEER

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

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SPECIAL PROVISION NO.

FOR

HI - DRO CUSHION - TYPE
ENERGY - ABSORBING BARRIER SYSTEM

This Special Provision shall be applicable only when indicated on the plans or in the proposal and, when so indicated, shall supersede any conflicting provisions of the Department's Standard Specifications.

I. DESCRIPTION

This barrier system utilizes the principle of controlled expulsion of water from flexible tubes or bags to arrest or divert highway vehicles encroaching collision-ward upon rigid objects appurtenant to designated roadway sites. It shall consist of water-filled cells arrayed between diaphragms and fender panels, anchored by cables and other necessary hardware. These barrier modules shall be as manufactured by Energy Absorption Systems, Inc. of Chicago, Illinois and shall be assembled and erected as shown on the plans and in accordance with the provisions herein.

II. MATERIALS

A. CELLS

1. SOLID-VINYL-WALLED CELLS. These cells shall be hollow, vinyl plastic cylinders having 1/4-inch thick walls and integral bottoms. The nominal outside diameter shall be 6 inches. The cells shall be nominally 40 inches in height unless otherwise indicated on the plans. These cells shall be used in the nose portion of the cell-sandwich units and in the assembly of Hi-Dro Cushion Cell Clusters.

   An insert containing sharp-edged orifices to regulate the release of water and an evaporation control cap shall be permanently fixed into the upper end of each cell.

   The material used in the manufacture of the cells shall be vinyl plastic formulated from high molecular weight, homo-polymer vinyl resins combined with totally primary plasticizing systems.

   The plasticizers shall be chosen so as to produce a vinyl possessing high strengths and remaining flexible in both high and low temperatures. Ultra-violet stabilizers, heat

stabilizers, anti-bacteriological agents and other additives shall be utilized to give maximum protection and long life in outdoor environments.

2. FLEXIBLE CELL CARTRIDGES. These cylinderical cartridges (bags) shall be vinyl-coated nylon fabric, Shelter-lite style 3022-RG-0, or equal. The base fabric shall consist of 6.1 ounces of nylon and 16 ounces of vinyl to produce a total weight of 22 ounces per square yard. It shall remain flexible and water tight in extremes of heat and cold.

The bottoms of these cartridges shall be closed to form a leak-proof bag. An insert containing sharp-edged orifices to regulate the release of water and an evaporation control cap shall be permanently fixed into the top end.

The flexible cell cartridges shall have an outside diameter of approximately 5-1/2 inches. They shall be provided in standard lengths of 24, 30, and 36 inches, as specified on the plans. These cartridges shall be mounted in plastic rings, fastened to and between interior panels and/or diaphragms, in the cell-sandwich portions of the barrier -- all in accordance with the plans and the manufacturer's installation details.

B. FASTENERS

Clustered cells shall be factory-assembled and fastened with self-drilling, heat-treated, sheet-metal screws (No. 14, Hexagonal Head) and speed nut-washer combinations, cadium plated or hot-dip galvanized. The fasteners shall withstand a torque of 142 inch-pounds. The cells shall be joined at tops and bottoms. Piles of clusters shall be joined at the construction site. Three or more fasteners shall be used to form contiguous cells. Attachments to the structural backing system may be accomplished with straps and/or fasteners specified above, or as shown on the drawings.

C. MISCELLANEOUS METALWORK

All metal shall be ASTM A36 unless otherwise specified, and it shall be hot-dip galvanized or painted.

D. CABLES

The two, 7/8-inch diameter, cables shall be galvanized, 6 x 19 wire ropes, or an approved equal.

The four restoring (pull out) cables shall be 3/8-inch, galvanized, flexible, 7 x 12 wire ropes, or an approved equal.

E. DIAPHRAGM, FENDER PANELS, and INTERIOR PANELS

1. Diaphragms and Fender Panels shall be pre-fabricated and furnished by the manufacturer.
   a. Diaphragms shall generally be 1-1/2 inch thick plywood coated on both sides with fiberglass.
   b. Fender Panels shall be plywood of specified thickness and shall be coated on both sides with fiberglass. The outer side shall have a glossy finish.

2. The Interior Panels shall consist of overlaid plywood. The edges shall be sealed and painted.

F. COLOR

The solid-vinyl-walled cells and the fender panels shall be yellow in color.

G. STRUCTURAL BACKING SYSTEMS

Structural backup facilities to be constructed for and in conjunction with the barrier system shall be as designated on the plans or as directed by the engineer.

H. CELL FLUID

The solution to fill the cells shall be a mixture of water, 75 percent by weight, and anhydrous calcium chloride, 25 percent by weight, having a specific gravity of not less than 1.239.

I. ATTENDANT FEATURES

All attendant features of the barrier system, i.e. rings, straps, clips, hinges, anchors, and all other necessary items for the complete installation of the barrier system shall be installed as shown on plans or as directed by the engineer.

J. REPLACEMENT CELLS

Replacement cells, diaphragms, fender panels, interior panels and other replacement items shall be delivered in the quantity specified in the plans or as directed by the engineer. Replacement items shall be bid as a separate item.

III. CONSTRUCTION METHODS

The barrier shall be constructed as depicted on the plans or as directed by the engineer. The cells shall be filled with the designated brine. Any spilled brine or chloride shall be washed from the roadway surface.

IV. PAYMENT

Payment shall be at the contract lump sum price bid, which price constitutes full payment for furnishing, hauling, and placing the required materials for permanent installation on the initial barrier, and for furnishing any labor, equipment, tools, and incidentals that may be necessary for installation of the barrier system.