Dynamic Tests of California Type 9 Bridge Barrier Rail and Type 8 Bridge Approach Guardrail

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The results of one full-scale vehicle impact test into the California type 9 bridge barrier rail and three tests into various modifications of the California type 8 bridge approach guardrail are reported. The results indicate that the type 9 bridge barrier rail and the final type 8 bridge approach guardrail designs will retain and redirect a 4,500-lb passenger vehicle, impacting at 60 mph and 25 deg, with tolerable deceleration rates, moderate vehicle damage, and minimal barrier damage. The bridge barrier rail and bridge approach guardrail, together, provide structural continuity and a pleasing appearance.

•HIGHWAY ENGINEERS are continually striving to improve their product. Efforts along this line are expended in a multitude of directions motivated by advances in technology, concern for safety and aesthetics, and a desire to give the public the greatest value for each tax dollar. In the area of highway barrier systems, significant improvements are being made as new concepts and designs are developed and tested.

The first series of vehicle impact tests on bridge rails by the California Division of Highways was conducted in the mid-1950s. These tests were initiated because of the serious operational deficiencies, primarily structural, that were showing up with the increased use of heavier, higher speed vehicles and higher speed highways. These and subsequent tests provided a better knowledge of the requirements for modern bridge rails and for the dynamic actions of impacting high-speed vehicles. From this early testing, for example, it was learned that vehicles impacting baluster-type bridge rails tended to snag on the openings, thereby causing severe vehicle decelerations and frequent rail failures.

As a result of these earlier tests, in 1962 the California Division of Highways settled on a design called the California type 1 bridge barrier rail (2). This design is composed of a single 5-in. diameter metal pipe railing mounted 15 in. above the top of a 21-in. high solid reinforced concrete parapet wall. The overall height of this barrier system is 36 in. This design has given good operational performance, both structurally and in the reduction of the severity of accidents. However, operational information indicated that the following aspects could be improved:

1. The type 1 bridge barrier rail is not self-cleaning. In certain areas, sand and other debris tend to pile up against the solid parapet wall.
2. Visibility through the railing is somewhat restricted, both for the motorist on the bridge wishing to view the surrounding scenery and from a safety standpoint for the motorist needing adequate sight distance from an approach ramp adjacent to the structure.

In 1965-1966, these considerations led to the design, testing, and subsequent use of the California type 8 bridge rail (1). The design is composed of two 2- by 6-in. steel

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Figure 1.

rectangular tube rails mounted 15 and 27 in. high on welded, open-type steel posts spaced 10 ft on centers. From the standpoint of structural adequacy and appearance, this bridge rail also performs well. However, operational experience has indicated that on higher structures motorists tend to shy away from this low, open, fragile-appearing railing and thus crowd the inner lanes of traffic.

The inadequate appearance of the California type 8 bridge rail then led to the compromise design of the California type 9 bridge barrier rail. The type 9 bridge rail and the California type 8 bridge approach guardrail used with it are the subject of the tests covered by this report. The type 9 bridge rail consists of a single 2- by 6-in. steel rectangular tube rail attached to welded steel posts mounted on a 15-in. high concrete parapet for an overall barrier height of 27 in. The double-rail type 8 system was adapted as a bridge approach guardrail that maintains structural and aesthetic continuity while protecting the motorist from end-on collision into the bridge rail.

In this study, the new California type 9 bridge barrier rail and the new California type 8 bridge approach guardrail were subjected to controlled vehicle impact tests. Thus, the primary objectives of this research project were to (a) test the California type 9 bridge barrier rail, (b) test the California type 8 approach guardrail flare, and (c) develop and test subsequent design modifications to the barriers as determined from the results of the tests on the initial designs.

TEST PARAMETERS

The test vehicles used in this study were 1966 sedans weighing approximately 4,500 lb including a dummy and instrumentation. The test procedures taken to prepare, remotely control, and target the test vehicle are similar to those used in past test series and detailed in previous California reports (3, 4). These test parameters generally meet the guidelines established by the Highway Research Board Committee on Guardrails and Guide Posts (5).

INSTRUMENTATION

Photographic and mechanical instrumentation procedures and equipment employed in this test series are similar to those used in past test series and are detailed in previous California reports (3, 4).

DESIGN AND PERFORMANCE

Test 172—California Type 9 Bridge Barrier Rail

The California type 9 bridge barrier rail (Fig. 1) consists of a single steel rail mounted 12 in. above the top of a 15-in. high reinforced concrete parapet wall. The total barrier rail height is 27 in. from the bridge deck to the top of the steel rail.

The rail is fabricated from 6-in. by 2-in. by 12.02-lb structural steel rectangular tubing

Figure 2.

conforming to ASTM Specification A 500, Grade B. An interior sleeve-type rail splice, proven effective in a previous test series (1), is used. The minimum length of a steel rail segment is 20 ft except at the end of the barrier downstream to traffic where a shorter length is bent down at a 36-in. radius to butt against the top of the parapet. At the end of the barrier upstream to traffic, the single steel rail extends beyond the end of the parapet for transition connection with the bridge approach guardrail.

The rail is supported on welded steel posts spaced at 10-ft centers and fabricated from ASTM Specification A 36 structural steel. Two ¾-in. steel bolts, stud-welded to the rail, are used to connect the rail to each post. The posts are secured to the parapet by two high-strength bolts, one ¾-in. diameter by 8 in. and the other 1-in. diameter by 10 in., cast in the concrete (Fig. 2).

For this test installation, the concrete parapet was 65 ft long and was constructed on a reinforced concrete simulated cantilevered bridge deck. The deck and parapet reinforcing, as well as other details of the type 9 bridge barrier rail constructed for test 172, are shown in Figure A1 of the Appendix. This barrier rail system was designed in accordance with the requirements of the 1965 AASHO Standard Specifications for Highway Bridges.

The vehicle in test 172 impacted the barrier midspan between posts 3 and 4 at 57 mph and 26 deg. Because of the relatively low parapet height (15 in.) in relation to the vehicle bumper (Fig. 3), the bumper and leading frame members projected over the concrete parapet on impact.

As the vehicle progressed through impact, the front bumper and chassis snagged on the vertical flanges of post 4, causing the fillet welds connecting the post flange to the horizontal mounting bar to fail. This severe loading was also transmitted to the anchor bolts, causing some spalling of the concrete parapet (Fig. 4). The failure at post 4 increased lateral and longitudinal loadings to posts 3 and 5. Post 5, located 15 ft downstream of initial impact, sustained only minor flange deformation. However, post 3, located 5 ft upstream, was apparently subjected to higher loading, as evidenced by spalling of the concrete around the anchor bolts in addition to slight flange deformation (Fig. 5). Even though the rail was released at post 4, the maximum permanent rail deflection was only 0.42 ft laterally and 0.45 ft vertically. All deflection occurred between posts 3 and 5 (Fig. 6).

Figure 3.

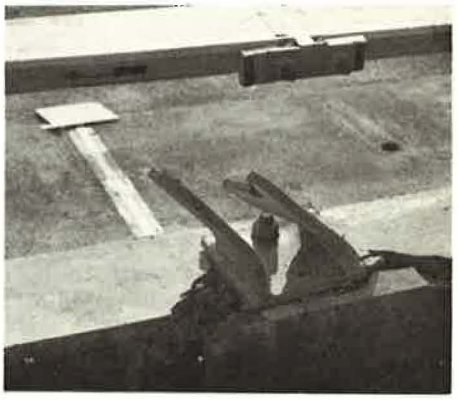

Figure 4.

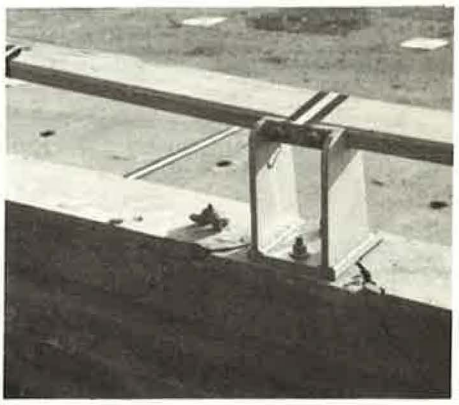

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Barrier damage was considered moderate under the severe impact conditions of this test. Rail damage would require replacement of one post and two rail sections. The concrete parapet could have been repaired by straightening the anchor bolts at post 3, chipping out the spalled concrete at posts 3 and 4, and patching with an epoxy-cement grout.

Vehicle dynamics were considered satisfactory with minimal jump and no tendency to roll. Vehicle-barrier contact was approximately 15 ft and the exit angle was about 6 deg. Pertinent data on this test are shown in Figure A2 of the Appendix. The vehicle damage, although relatively severe, is characteristic of high-speed impact at relatively high angles into nonyielding barriers (Fig. 7).

Test 171—California Type 8 Bridge Approach Guardrail, Initial Design

The initial bridge approach guardrail design (Fig. 8) was adapted from the California type 8 bridge rail design developed and tested in 1965-1966 (1). This design uses two 6-in. by 2-in by 12.02-lb structural steel rectangular tube rails mounted 15 and 27 in. to the top above the ground. However, the welded steel posts, spaced at 10 ft on centers from the earlier bridge rail, are altered to permit attachment over 8- by 8-in. Douglas fir posts embedded 36 in. in drilled holes in original ground with tamped backfill.

The rail segments are fastened together with an interior sleeve-type rail splice using two $^3/_4$-in. diameter by $3^1/_4$-in. long through bolts to transmit tensile forces. The

Figure 9.

Figure 10.

rails are secured to each steel post with two ¾-in. diameter welded stud bolts (Fig. 9) in the same manner employed on the California type 8 and 9 bridge rails.

The upper and lower rails in the leading 10 ft of approach guardrail at the end upstream of traffic are bent down on 20-ft and 19-ft radii respectively. The end of each rail is anchored with one ¾-in. diameter by 12-in. long high-strength steel bolt cast in the 24- by 54- by 24-in. deep reinforced concrete anchor block (Fig. 10). In plan view, the upstream end of the approach guardrail is offset 3 ft from the projected straight line of the bridge rail (Fig. 11). This offset is achieved by curving all but the end 10 ft of the approach guardrail on a 230-ft radius.

At the downstream end, the upper approach rail was spliced to the single rail of the type 9 bridge barrier rail. The lower approach rail was secured to the bridge barrier rail concrete parapet with two ¾-in. diameter by 12-in. long high-strength bolts cast in the parapet (Fig. 12). The length of the type 8 bridge approach guardrail was 38.5 ft and the length of the type 9 bridge rail to which it was attached was 65 ft, providing a total installation length for test 171 of 103.5 ft. Details of the type 8 bridge approach rail design used in this test are shown in Figure A3 of the Appendix.

In order to determine the redirecting characteristics of this system, a 60-mph, 25-deg impact was planned to contact the approach guardrail approximately 20 ft from the upstream end. However, because of an inaccuracy in vehicle steering control, the test vehicle in test 171 impacted the approach guardrail within the upstream sloping section approximately 4 ft from the leading end at 60 mph and 27 deg.

At the point of initial contact, the upper approach rail was approximately 15 in. above the pavement. This low height permitted the bumper and leading frame members of the vehicle to pass over the rail upon impact. The sloping rails imparted both a vertical force and a rolling moment to the vehicle as it vaulted the barrier. The vehicle rolled in a counterclockwise direction while it was airborne before landing on its left side. It then rolled over onto its top as it skidded an additional 140 ft before coming to rest. Pertinent data on this test are shown in Figure A4 of the Appendix.

The rails deflected laterally and high tensile forces caused the upstream rail end anchor bolts to strip (Fig. 13). The loss of upstream end anchorage transmitted additional impact loading downstream to the barrier posts. The timber portion of post 1 was sheared at ground level and post 2 was severely fractured (Fig. 14). Damage

Figure 11.

Figure 12.

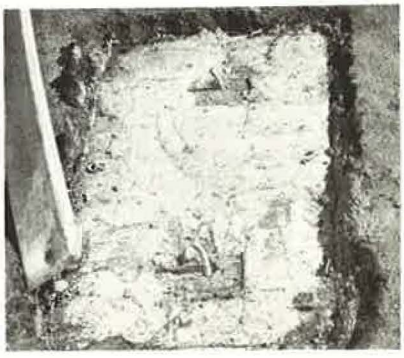

Figure 13.

Figure 14.

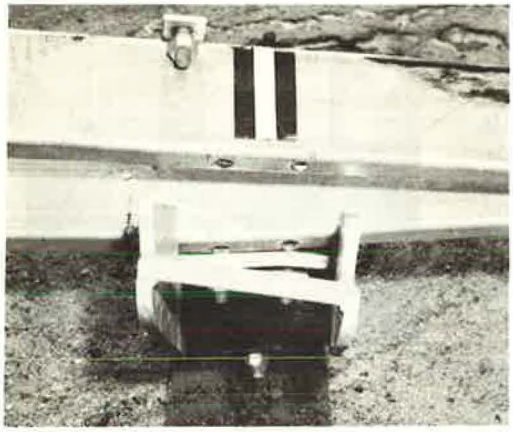

Figure 15.

Figure 16.

to the steel portion occurred at post 1 only. This damage consisted of moderate deformation of the side flanges and the rail mounting bars.

All tubular steel rail sections were damaged. Stud-weld failures occurred on the upper rail at all three approach guardrail posts and on the lower rail at post 1 only (Figs. 15 and 16). However, there were no rail splice failures and the downstream rail-to-parapet connection was not damaged.

Vehicle damage consisted of moderate sheet metal deformation of the left side and top. Deformation of the front bumper occurred when it impacted post 1 and snagged under the upper rail (Fig. 17).

Test 173—Type 8 Bridge Approach Guardrail, Modified

For this second approach guardrail test, several modifications were made to the post and end anchorage details to correct deficiencies noted in the design used in test 171. At the end upstream to traffic, the rail end anchorage was substantially strengthened by welding a steel plate to both the upper and lower rails and securing each with two 1-in. diameter by 15-in. long high-strength bolts cast in separate 2-ft diameter by 4-ft deep cylindrical reinforced concrete anchors (Fig. 18). The downstream rail ends were attached to the type 9 bridge barrier rail as in test 171 except that the cast-in anchor bolts were increased in size from a $^3/_4$-in. to a 1-in. diameter and the bolt edge distance from the face of the parapet was increased to 4 in. from 3 in.

The composite fabricated steel and timber guardrail post used in test 171 was replaced with fabricated steel posts at 10-ft centers anchored with three 1-in. diameter by 15-in. long high-strength bolts cast in 2-ft diameter by 4-ft deep cylindrical reinforced concrete cast in drilled hole footings (Fig. 19).

As an additional measure, the interior sleeve rail splice used in test 171 was strengthened by the use of a $1^3/_8$-in. solid

Figure 17.

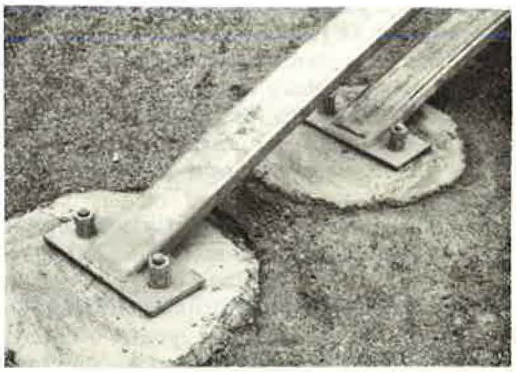

Figure 18.

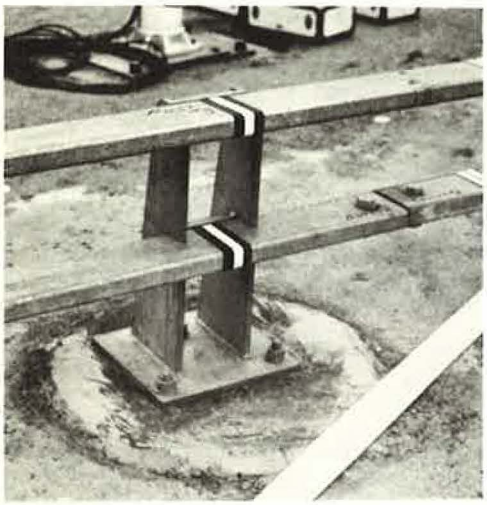

Figure 19.

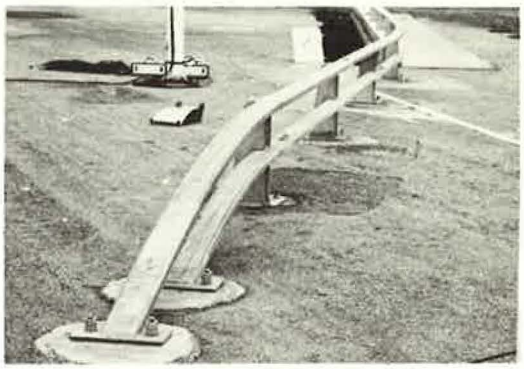

Figure 20.

Figure 21.

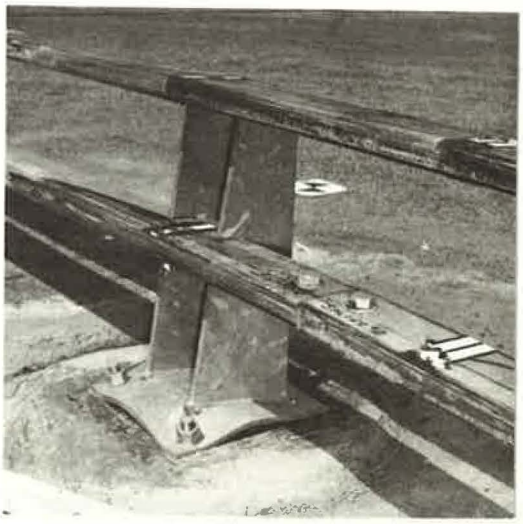

Figure 22.

steel splice plate and the splice bolts were increased from ¾ in. to 1 in. in diameter. Details on the bridge approach guardrail design employed in test 173 are shown in Figure A5 of the Appendix.

For this test installation, the 3-ft upstream end offset was obtained by curving the 17 ft of rail adjacent to the bridge rail at a 170-ft radius with the remaining 31.5 ft of rail being constructed on a tangent. The total approach guardrail length was 48.5 ft and bridge rail length was 65 ft, providing a total installation length for test 173 of 113.5 ft (Fig. 20). The initial impact point for this second approach guardrail test was near the center of the installation 2.5 ft upstream of post 3 at 61 mph and 24 deg.

The height of the lower rail (15 in.) in relation to the vehicle bumper (Fig. 21) permitted the bumper and chassis to project over the lower rail upon impact as the upper rail "knifed" into the vehicle body just below the headlamp.

This penetration of the vehicle into the guardrail permitted metal components to snag on the steel posts. The weld ruptures and base plate deformation at post 3 are indicative of this high loading (Fig. 22). There were no anchor-bolt, rail-splice, or stud-bolt failures. However, the guardrail was under considerable lateral stress, as indicated by the displacement between the concrete footings under the fabricated steel

Figure 23.

Figure 24.

posts and the surrounding soil. There was also a slight weld rupture and base plate deformation at post 4, which was 12.5 ft downstream of impact (Fig. 23).

Considering the severity of the impact, overall guardrail damage was relatively minor, with only one post sustaining deformation extensive enough to require replacement. Three approach rail sections were also deformed with maximum permanent deflection of 0.5 ft laterally and 0.15 ft vertically. Even after this severe impact, all components were intact and the approach guardrail was still functional (Figs. 24 and 25).

There was no damage to any of the concrete portions of the bridge approach guardrail or the bridge barrier rail, and repairs would consist only of replacing the deformed post and rail sections in the approach guardrail. However, if deemed necessary, interim repairs could be effected by straightening the bent members. Based on the results of test 173, it appears that this guardrail would perform satisfactorily for fairly severe impacts with little maintenance being required.

Vehicle dynamics were considered tolerable with minimal jump and only a moderate tendency to roll. Vehicle-barrier contact was approximately 10 ft and the exit angle was about 19 deg. Pertinent data on this test are shown in Figure A6 of the Appendix.

Vehicle damage consisted of moderate deformation of the left front wheel and chassis and extensive sheet metal deformation at the left front end. The left front fender was deeply indented where the upper rail knifed into it (Fig. 26). Damage to the left side, rear fender, and rear bumper occurred during the secondary impact as

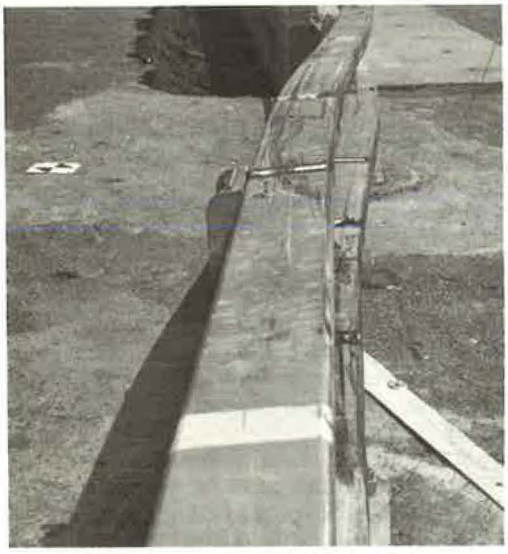

Figure 25.

Figure 26.

the vehicle was redirected parallel to the barrier (Fig. 27).

Figure 27.

Test 174—Type 8 Bridge Approach Guardrail

Results of the previous two bridge approach guardrail tests (tests 171 and 173) suggested further design refinements for this third and final bridge approach guardrail test installation (test 174). The first test (test 171) had indicated that the upstream end anchorage system and the barrier post design were inadequate. In the second test (test 173), an attempt was made to correct these deficiencies by using a strengthened tubular rail end anchorage attachment and a modified post design. The strengthened end anchorage attachment was considered adequate and was not changed for test 174. However, the two separate cylindrical concrete footings used to anchor the rails were replaced by a single, 36- by 42- by 24-in. deep rectangular reinforced concrete footing.

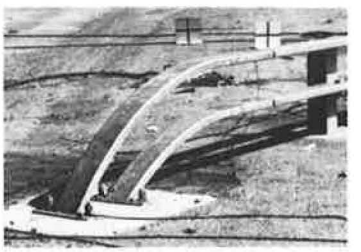

Figure 28.

Based on the previous two tests, it was also felt that the 10-ft long sloping upstream rail end section presented an excessive area of vulnerability to an errant vehicle. Therefore, this sloping section was reduced in length to 4 ft 7 in., with the lower rails curved down at 6-ft and 5-ft radii respectively (Fig. 28).

Figure 29.

The modified welded steel post design used in test 173, although structurally adequate, was expensive and difficult to construct, repair, and/or replace. Therefore, for test 174 a more economical and practicable design was used consisting of steel wide-flange beam (6WF25) posts on 10-ft centers embedded in 36-in. deep by 18-in. diameter concrete footings (Fig. 29).

In lieu of the interior sleeve splice design used in the previous tests, rail splicing was accomplished by bolting the rail section ends to a 5- by $2\frac{1}{2}$- by $\frac{1}{2}$-in. steel angle with 1-in. diameter by 4-in. long high-strength bolts. The steel angle was secured, along with the rails, to the steel posts by $\frac{3}{4}$-in. stud bolts welded on the tubular rail (Figs. 30 and 31). The steel angle was used only at tubular rail splices. All other rail-to-post attachment was accomplished utilizing the welded stud bolt with a $\frac{1}{2}$-in. thick backup spacer.

Figure 30.

The same rail-to-parapet connection was used at the downstream end as in the preceding test. Details on the final type 8 bridge approach guardrail design used in test 174 are shown in Figure A7 of the Appendix. The guardrail was flared to a 3-ft offset at the upstream end by curving the 18.5 ft of approach rail adjacent to the bridge rail to a 240-ft radius. The remaining 30 ft of rail was constructed on a straight tangent. The total approach guardrail length was 48.5 ft and the bridge barrier rail length

Figure 31.

Figure 32.

Figure 33.

was 65 ft, thus providing a total installation length for test 174 of 113.5 ft (Fig. 32).

The initial impact point for this third and final approach guardrail test was approximately midspan between posts 3 and 4 at 60 mph and 26 deg. As in the previous tests, the front bumper and left front chassis members projected over the 15-in. high lower rail as the upper rail indented a deep groove into the vehicle body.

Vehicle dynamics through impact were considered to be good with no tendency to jump and only a minimal roll toward the barrier. Vehicle-barrier contact was approximately 10 ft and the exit angle about 19 deg. Pertinent data on this test are shown in Figure A8 of the Appendix.

Vehicle damage was moderate, with substantial sheet metal deformation at the left front end (Fig. 33). Deformation of the left side body panels and the left front wheel were less severe than in test 173. The secondary impact from the rear of the vehicle striking the barrier was also less severe, as indicated by the minimal damage to the left rear body panels and rear bumper.

The guardrail damage from this severe impact was relatively minor. Although a butt-welded splice in the upper rail at post 3 did fracture, as shown in Figures 34 and 35, this failure was attributed to poor welding practice. An internal welding backup plate was not used, resulting in poor weld penetration. Future specifications will require that a backup plate be used on all butt-welded rail elements to ensure full weld penetration. As shown in Figure 34, the rail elements downstream of post 3 were twisted up at the rail splices. This is indicative of the torsional force applied

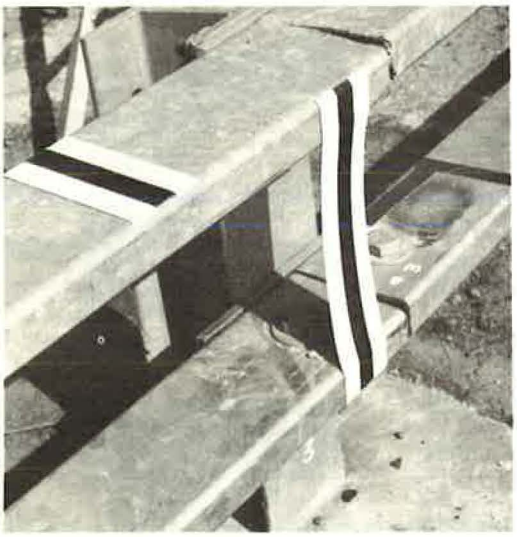

Figure 34.

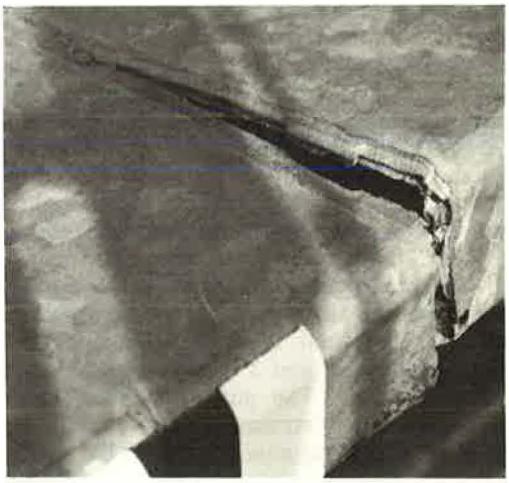

Figure 35.

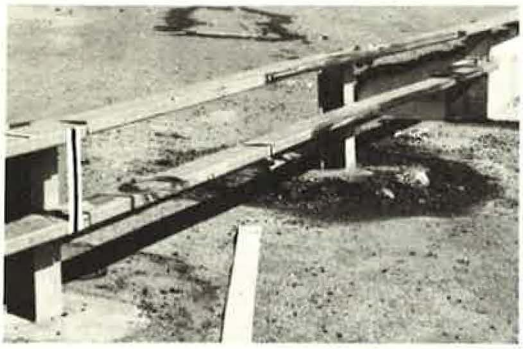

Figure 36.

Figure 37.

to the rails. Post 3, although rotated back approximately 10 deg, was not deformed. Three rail sections were only slightly deformed, with maximum residual deflections of 0.23 ft laterally and 0.03 ft vertically. After impact all barrier components were intact and the barrier was still considered to be functional (Fig. 36). The concrete parapet at the downstream lower rail connection was cracked. However, the anchor bolts were not deformed and would not require replacement (Fig. 37).

It was concluded that the final California type 8 bridge approach guardrail design in test 174 fulfills the current requirements for an approach guardrail leading up to a rigid-type bridge barrier rail. This approach guardrail design is relatively economical to construct and the reduced vehicle damage and more tolerable vehicle damage observed show it to be an improvement over the two previous preliminary designs.

CONCLUSIONS

The following conclusions are based on an analysis of the results of the full-scale vehicle impact tests conducted during this test series:

1. The type 9 bridge barrier rail design impacted in test 172 will retain and redirect a 4,500-lb sedan impacting at a 25-deg approach angle and a speed of 60 mph. Barrier damage from such an impact can be expected to be moderate but repairable and the barrier will remain effective with all critical components intact.
2. The initial type 8 bridge approach guardrail design impacted in test 171 will not retain nor redirect a 4,500-lb sedan impacting at a wide angle and high speed when impact is within the upstream sloping rail section. Barrier damage also indicated that the upstream bolted rail anchorage and the composite fabricated steel and timber post design were structurally inadequate. It was further concluded that any impact into the sloped rail section at the upstream end of the bridge approach guardrail could cause the vehicle to overturn, and therefore this section should be as short as possible to reduce the area of vulnerability.
3. The modified type 8 bridge approach guardrail design impacted in test 173 will retain and redirect a 4,500-lb sedan impacting at a 25-deg approach angle and a speed of 60 mph. However, this barrier design with its fabricated steel posts and reinforced concrete post anchors is expensive to fabricate and difficult to construct.
4. The final type 8 bridge approach guardrail design impacted in test 174 will retain and redirect a 4,500-lb sedan impacting at a 25-deg approach angle and a speed of 60 mph. In addition to performing satisfactorily under a severe impact, this final design utilizing a shorter, stronger upstream rail anchorage and steel wide-flange (6WF25) post is considered relatively easy and economical to fabricate and construct.

ACKNOWLEDGMENT

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and conclusions expressed in this paper are those of the authors and not necessarily those of the Bureau of Public Roads.

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Appendix

The following figures contain pertinent data and photographs of the impact tests discussed in this report.

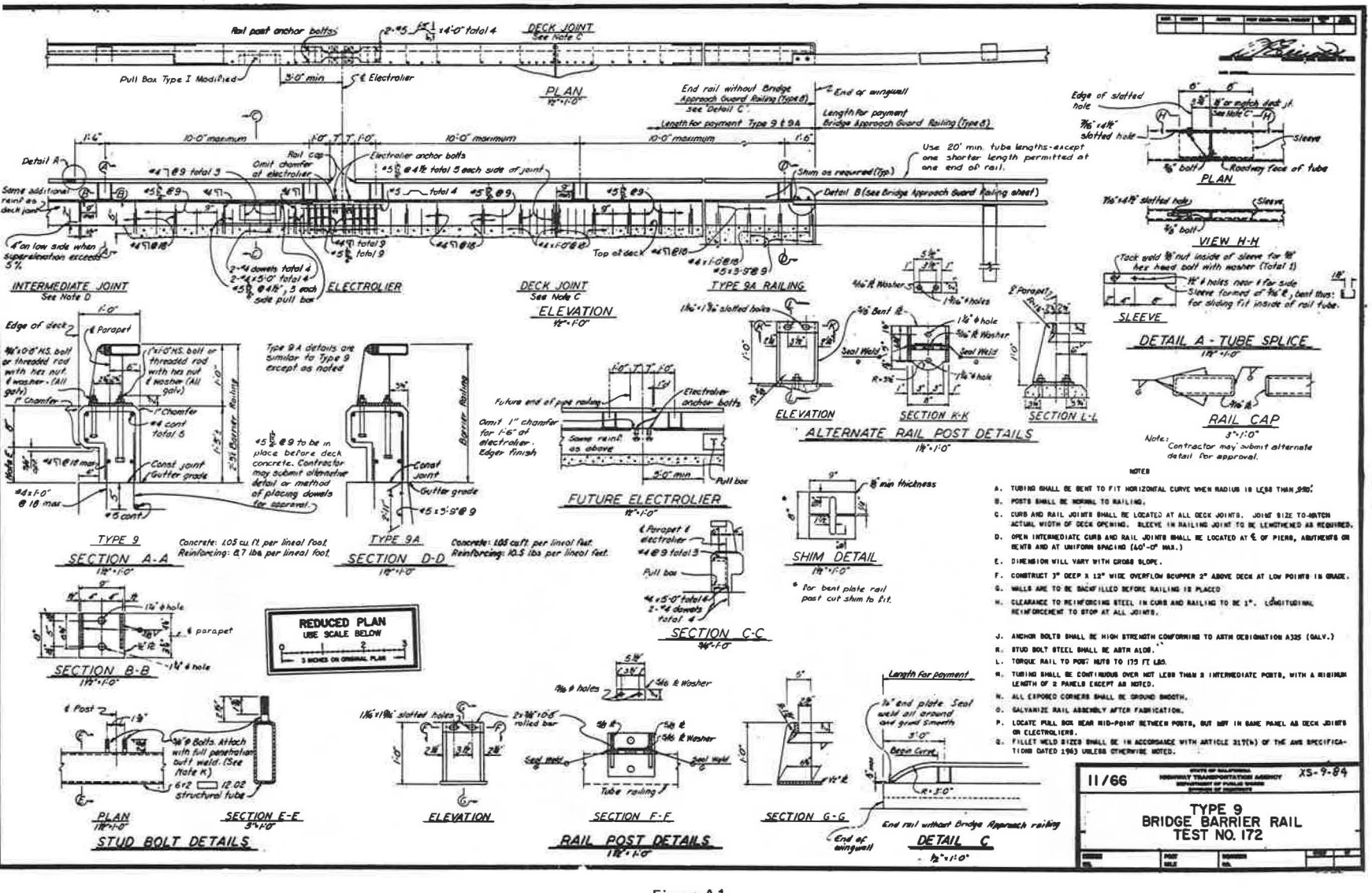

PLAN
DECK JOINT
See Note C
Rail post anchor bolts
Pull Box Type I Modified
℄ Electrolier
End rail without Bridge Approach Guard Railing (Type 8)
see Detail C
End of wingwall
Length for payment Type 9 & 9A
Length for payment Bridge Approach Guard Railing (Type 8)
Use 20' min. tube lengths-except one shorter length permitted at one end of rail.
Shim as required (Typ.)
Detail B (see Bridge Approach Guard Railing sheet)
Detail A
Rail cap
Omit chamfer at electrolier
Electrolier anchor bolts
Same additional reinf as deck joint
4" on low side when superelevation exceeds 5%
INTERMEDIATE JOINT
See Note D
ELECTROLIER
DECK JOINT
See Note C
ELEVATION
TYPE 9A RAILING
Top of deck
Edge of slotted hole
Sleeve
Roadway face of tube
VIEW H-H
SLEEVE
DETAIL A - TUBE SPLICE
RAIL CAP
Note: Contractor may submit alternate detail for approval.
Edge of deck
℄ Parapet
Type 9A details are similar to Type 9 except as noted
Barrier Railing
Const joint
Gutter grade
TYPE 9
SECTION A-A
Concrete: 1.05 cu. ft. per lineal foot
Reinforcing: 8.7 lbs. per lineal foot
TYPE 9A
SECTION D-D
Concrete: 1.05 cu. ft. per lineal foot
Reinforcing: 10.5 lbs. per lineal foot
Future end of pipe railing
Omit 1" chamfer for 1'-6" at electrolier. Edger finish
Same reinf as above
Pull box
FUTURE ELECTROLIER
ALTERNATE RAIL POST DETAILS
SECTION K-K
SECTION L-L
SHIM DETAIL
* for bent plate rail post cut shim to fit.
SECTION C-C
SECTION B-B
REDUCED PLAN
USE SCALE BELOW
3 INCHES ON ORIGINAL PLAN
NOTES
A. TUBING SHALL BE BENT TO FIT HORIZONTAL CURVE WHEN RADIUS IS LESS THAN 950'.
B. POSTS SHALL BE NORMAL TO RAILING.
C. CURB AND RAIL JOINTS SHALL BE LOCATED AT ALL DECK JOINTS. JOINT SIZE TO MATCH ACTUAL WIDTH OF DECK OPENING. SLEEVE IN RAILING JOINT TO BE LENGTHENED AS REQUIRED.
D. OPEN INTERMEDIATE CURB AND RAIL JOINTS SHALL BE LOCATED AT ℄ OF PIERS, ABUTMENTS OR BENTS AND AT UNIFORM SPACING (40'-0" MAX.)
E. DIMENSION WILL VARY WITH CROSS SLOPE.
F. CONSTRUCT 3" DEEP X 12" WIDE OVERFLOW SCUPPER 2" ABOVE DECK AT LOW POINTS IN GRADE.
G. WALLS ARE TO BE BACKFILLED BEFORE RAILING IS PLACED
H. CLEARANCE TO REINFORCING STEEL IN CURB AND RAILING TO BE 1". LONGITUDINAL REINFORCEMENT TO STOP AT ALL JOINTS.
J. ANCHOR BOLTS SHALL BE HIGH STRENGTH CONFORMING TO ASTM DESIGNATION A325 (GALV.)
K. STUD BOLT STEEL SHALL BE ASTM A108.
L. TORQUE RAIL TO POST NUTS TO 175 FT LBS.
M. TUBING SHALL BE CONTINUOUS OVER NOT LESS THAN 2 INTERMEDIATE POSTS, WITH A MINIMUM LENGTH OF 2 PANELS EXCEPT AS NOTED.
N. ALL EXPOSED CORNERS SHALL BE GROUND SMOOTH.
O. GALVANIZE RAIL ASSEMBLY AFTER FABRICATION.
P. LOCATE PULL BOX NEAR MID-POINT BETWEEN POSTS, BUT NOT IN SAME PANEL AS DECK JOINTS OR ELECTROLIERS.
Q. FILLET WELD SIZES SHALL BE IN ACCORDANCE WITH ARTICLE 217(h) OF THE AWS SPECIFICATIONS DATED 1963 UNLESS OTHERWISE NOTED.
℄ Post
Bolts. Attach with full penetration butt weld. (See Note K)
6x12 12.02 structural tube
PLAN
SECTION E-E
STUD BOLT DETAILS
ELEVATION
SECTION F-F
RAIL POST DETAILS
SECTION G-G
Length for payment
End rail without Bridge Approach railing
End of wingwall
DETAIL C
11/66
XS-9-84
TYPE 9
BRIDGE BARRIER RAIL
TEST NO. 172

Figure A1.

IMPACT + 0.01 Sec.

I + 0.06 Sec.

I + 0.16 Sec.

I + 0.26 Sec.

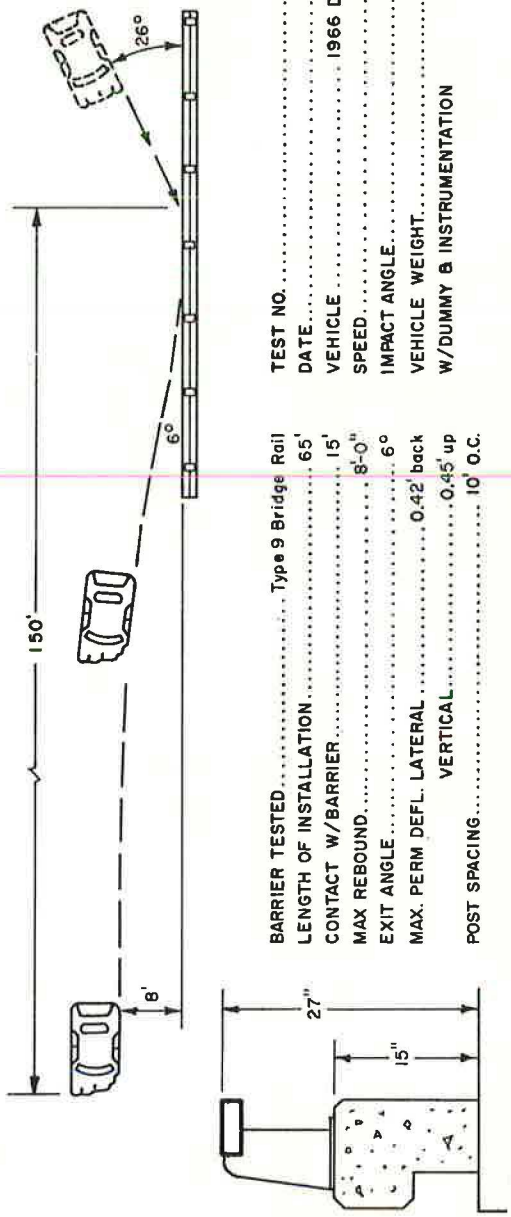


Figure A2.

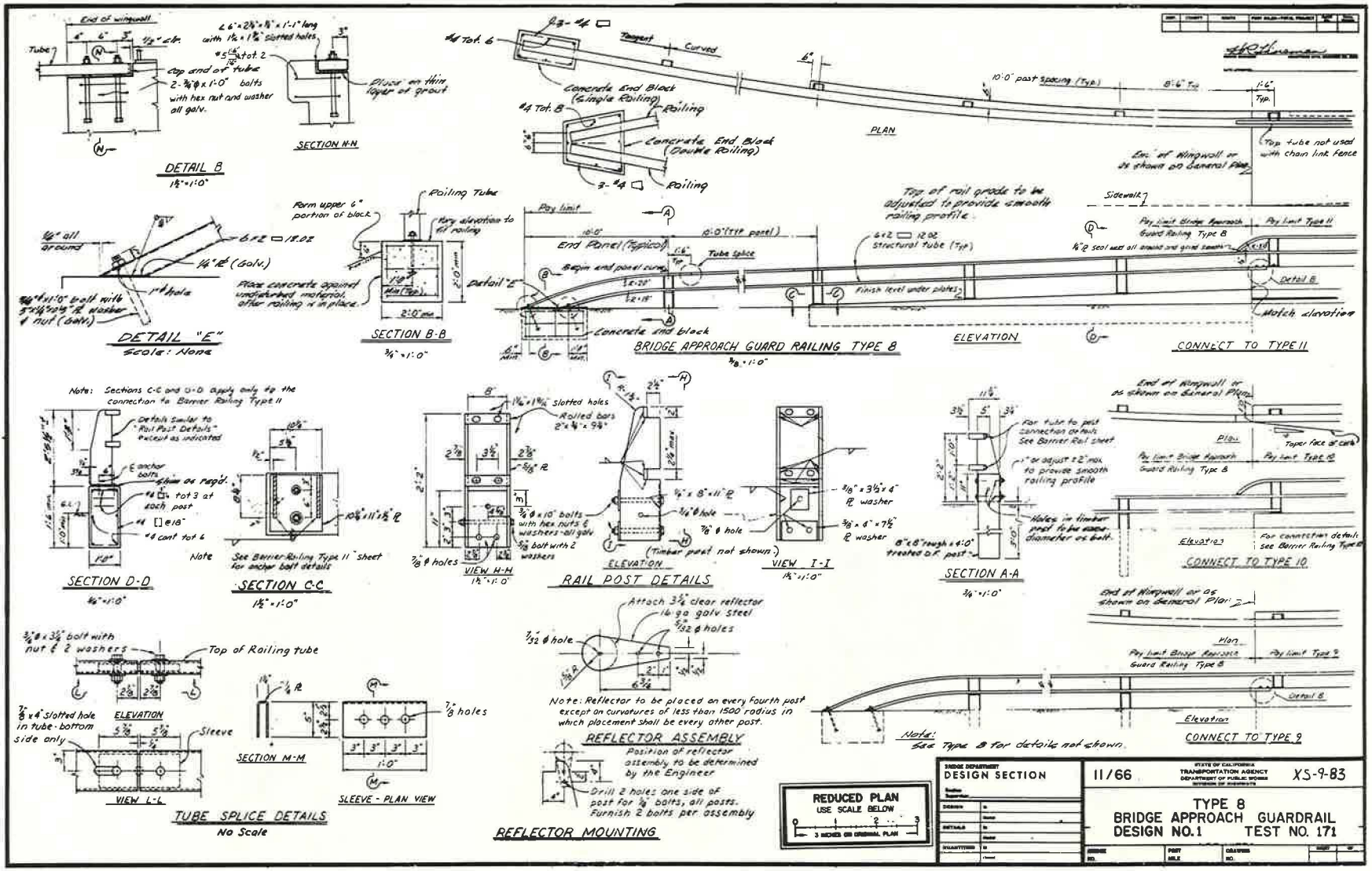
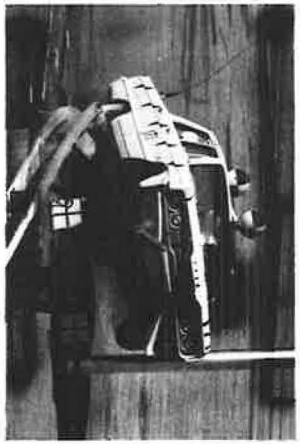

DETAIL B
SECTION N-N
PLAN
DETAIL "E"
Scale: None
SECTION B-B
BRIDGE APPROACH GUARD RAILING TYPE 8
ELEVATION
CONNECT TO TYPE 11
SECTION D-D
SECTION C-C
VIEW H-H
RAIL POST DETAILS
VIEW I-I
SECTION A-A
CONNECT TO TYPE 10
VIEW L-L
TUBE SPLICE DETAILS
No Scale
SECTION M-M
SLEEVE - PLAN VIEW
REFLECTOR ASSEMBLY
REFLECTOR MOUNTING
CONNECT TO TYPE 9
REDUCED PLAN
USE SCALE BELOW
DESIGN SECTION
11/66
XS-9-83
TYPE 8
BRIDGE APPROACH GUARDRAIL
DESIGN NO.1 TEST NO. 171

Figure A3.

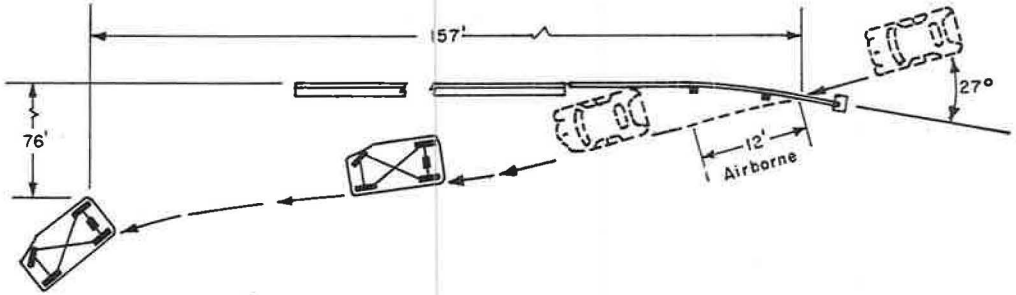
IMPACT

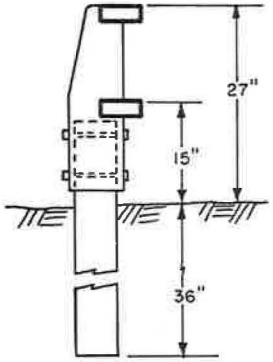
I + 0.15 Sec.



I + 0.30 Sec.

I + 0.60 Sec.





BARRIER TESTED	Type 8 B.A.G.
LENGTH OF INSTALLATION	103.5'
CONTACT W/BARRIER	Penetration
MAX REBOUND	Penetration
EXIT ANGLE	Penetration
MAX. PERM DEFL. LATERAL	0.5' back
VERTICAL	0.15' dn
POST SPACING	10' O.C.

TEST NO.	171
DATE	10-19-68
VEHICLE	1966 Dodge Sedan
SPEED	60 mph
IMPACT ANGLE	27°
VEHICLE WEIGHT W/DUMMY & INSTRUMENTATION	4540 #

Figure A4.

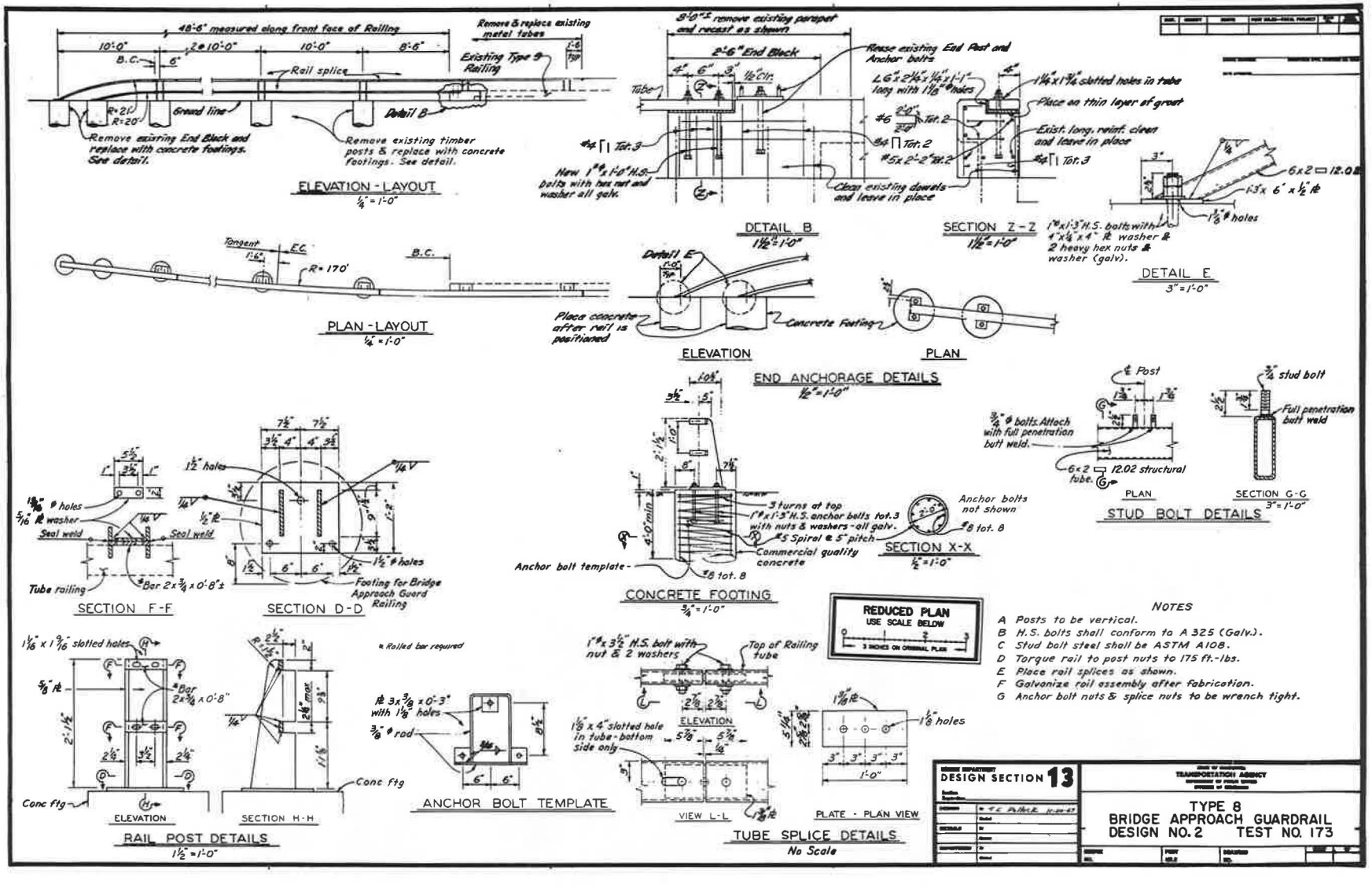

48'-6" measured along front face of Railing
10'-0"
2@10'-0"
10'-0"
8'-6"
B.C.
6"
Rail splice
Ground line
R=21'
R=20'
Detail B
Remove & replace existing metal tubes
Existing Type 9 Railing
Remove existing End Block and replace with concrete footings. See detail.
Remove existing timber posts & replace with concrete footings. See detail.
ELEVATION - LAYOUT
1/8" = 1'-0"
5'-0"± remove existing parapet and recast as shown
2'-6" End Block
Tube
New 1"ø x 1'-0" H.S. bolts with hex nut and washer all galv.
Reuse existing End Post and Anchor bolts
L 6" x 2 1/2" x 1/2" x 1'-1" long with 1 1/8" ø holes
1 1/4" x 1 3/4" slotted holes in tube
Place on thin layer of grout
Exist. long. reinf. steel and leave in place
Clean existing dowels and leave in place
DETAIL B
1 1/2" = 1'-0"
SECTION Z-Z
1 1/2" = 1'-0"
1"ø x 1'-3" H.S. bolts with 4" x 1/4" x 4" ⊥ washer & 2 heavy hex nuts & washer (galv).
6 x 2 ▭ 12.02
1'-3" x 6" x 1/2" ⊥
1 1/8" ø holes
DETAIL E
3" = 1'-0"
Tangent
E.C.
1'-6"
R = 170'
B.C.
PLAN - LAYOUT
1/4" = 1'-0"
Detail E
Place concrete after rail is positioned
Concrete Footing
ELEVATION
PLAN
END ANCHORAGE DETAILS
1/2" = 1'-0"
3 turns at top
1"ø x 1'-3" H.S. anchor bolts tot. 3 with nuts & washers - all galv.
#5 Spiral @ 5" pitch
Commercial quality concrete
Anchor bolt template
#8 tot. 8
CONCRETE FOOTING
3/4" = 1'-0"
Anchor bolts not shown
#8 tot. 8
SECTION X-X
1/2" = 1'-0"
℄ Post
3/4" ø bolts. Attach with full penetration butt weld.
6 x 2 ▭ 12.02 structural tube.
PLAN
3/4" stud bolt
Full penetration butt weld
SECTION G-G
3" = 1'-0"
STUD BOLT DETAILS
1 1/2" holes
1/4"
1/2" ⊥
1 1/2" ø holes
Footing for Bridge Approach Guard Railing
Tube railing
Bar 2 x 3/4 x 0'-8"±
Seal weld
SECTION F-F
SECTION D-D
1 1/16" x 1 3/16" slotted holes
5/8" ⊥
Bar 2 x 3/4 x 0'-8"
Conc ftg
ELEVATION
SECTION H-H
* Rolled bar required
⊥ 3 x 3/8 x 0'-3" with 1 1/8" holes
3/8" ø rod
ANCHOR BOLT TEMPLATE
1"ø x 3 1/2" H.S. bolt with nut & 2 washers
Top of Railing tube
1 1/2" x 4" slotted hole in tube - bottom side only
ELEVATION
VIEW L-L
1 1/8" ⊥
1 1/8" holes
PLATE - PLAN VIEW
RAIL POST DETAILS
1 1/2" = 1'-0"
TUBE SPLICE DETAILS
No Scale
REDUCED PLAN
USE SCALE BELOW
3 INCHES ON ORIGINAL PLAN
NOTES
A Posts to be vertical.
B H.S. bolts shall conform to A 325 (Galv.).
C Stud bolt steel shall be ASTM A108.
D Torque rail to post nuts to 175 ft.-lbs.
E Place rail splices as shown.
F Galvanize rail assembly after fabrication.
G Anchor bolt nuts & splice nuts to be wrench tight.
DESIGN SECTION 13
TRANSPORTATION AGENCY
TYPE 8
BRIDGE APPROACH GUARDRAIL
DESIGN NO. 2 TEST NO. 173

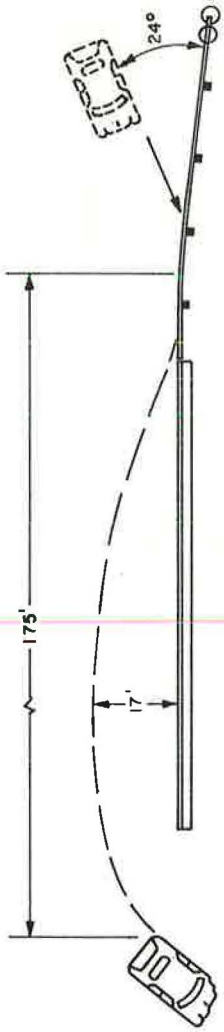
Figure A5.

IMPACT + 0.03 Sec.

I + 0.13 Sec.

I + 0.23 Sec.

I + 0.33 Sec.



BARRIER TESTED	Type B B.A.G.
LENGTH OF INSTALLATION	113.5'
CONTACT W/BARRIER	10'
MAX REBOUND	17'
EXIT ANGLE	19°
MAX. PERM DEFL. LATERAL	0.5' back
VERTICAL	0.15' up
POST SPACING	10' O.C.

TEST NO.	173
DATE	4-16-68
VEHICLE	1966 Dodge Sedan
SPEED	61 mph
IMPACT ANGLE	24°
VEHICLE WEIGHT	4540 #
W/DUMMY & INSTRUMENTATION	

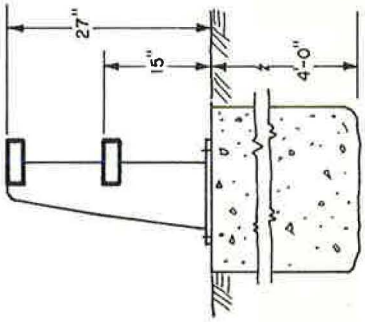


Figure A6.

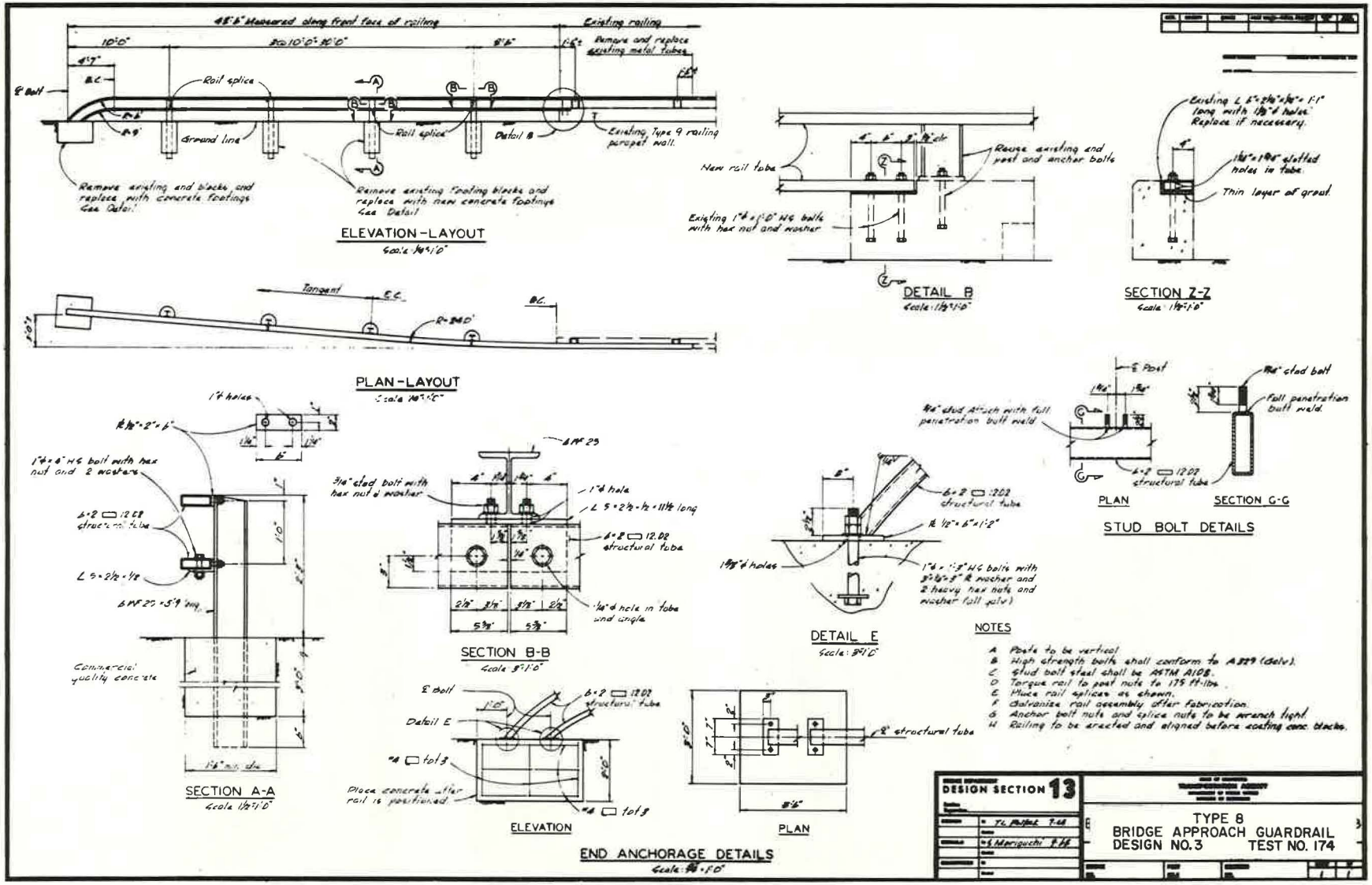
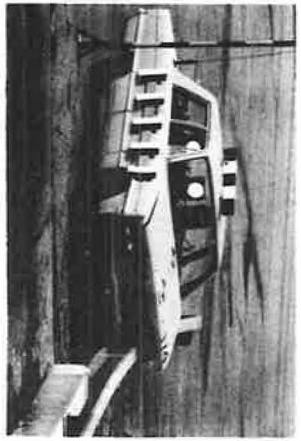
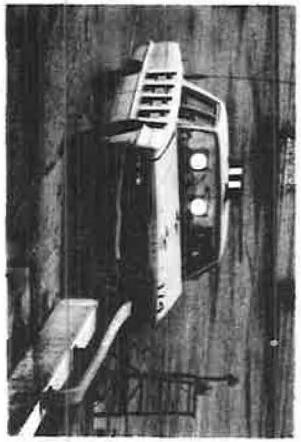

ELEVATION - LAYOUT
PLAN - LAYOUT
DETAIL B
SECTION Z-Z
SECTION A-A
SECTION B-B
DETAIL E
STUD BOLT DETAILS
PLAN
SECTION G-G
ELEVATION
PLAN
END ANCHORAGE DETAILS
NOTES
A Posts to be vertical
B High strength bolts shall conform to A325 (Delv).
C Stud bolt steel shall be ASTM A108.
D Torque rail to post nuts to 175 ft-lbs.
E Place rail splices as shown.
F Galvanize rail assembly after fabrication.
G Anchor bolt nuts and splice nuts to be wrench tight.
H Railing to be erected and aligned before casting conc. blocks.
DESIGN SECTION 13
TYPE 8
BRIDGE APPROACH GUARDRAIL
DESIGN NO. 3
TEST NO. 174

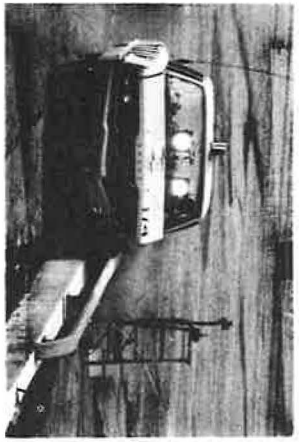
Figure A7.



IMPACT + 0.05 Sec.

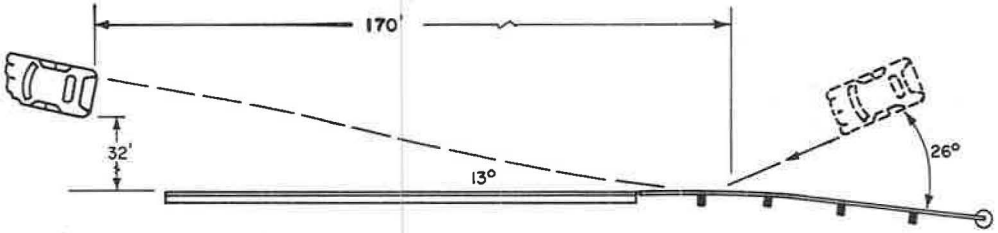


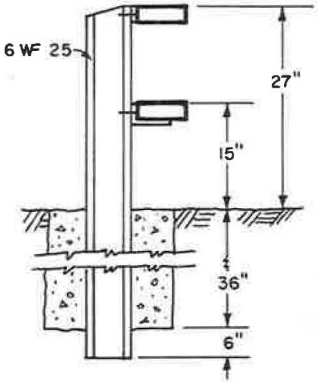
I + 0.15 Sec.



I + 0.20 Sec.

I + 0.35 Sec.





BARRIER TESTED	TYPE 8 B.A.G.
LENGTH OF INSTALLATION	113.5'
CONTACT W/BARRIER	10'
MAX REBOUND	32'
EXIT ANGLE	13°
MAX. PERM DEFL. LATERAL	0.23' back
VERTICAL	0.03' up
POST SPACING	10' O.C.

TEST NO.	174
DATE	3-11-69
VEHICLE	1966 Dodge Sedan
SPEED	60 mph
IMPACT ANGLE	26°
VEHICLE WEIGHT	4540 #
W/DUMMY & INSTRUMENTATION	

Figure A8.