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Barrier Deflection Characteristics of 31-inch W-Beam Guardrail Systems

by

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16. Abstract

The purpose of this research effort was to provide updated maximum deflection values based on simulations and crash test results for installations of 31-inch W-beam guardrail systems (SGR47). The research summarizes the results of computer simulations and crash tests to determine maximum deflections for new 31-inch W-beam guardrail systems with standard W6×8.5 strong posts with wood block-outs(SGR47) and varying post spacing (full-post spacing, half-post spacing, and quarter-post spacing) of both single and nested guardrail elements.

Phase I of the research was performed previously to gather the available crash test data on W-beam guardrail systems and is discussed under separate cover. Phase II of the research was focused on simulating additional 31-inch guardrail systems to broaden the range of system configurations for which deflection data is available. This phase fills in the gaps in crash test data by simulating useful configurations using BARRIERVII, a two-dimensional finite element analysis program. These simulations were used to predict the deflection characteristics of specific guardrail configurations. The resulting data was then combined with crash test data to update the AASHTO *Roadside Design Guide* barrier deflection guidance table.

The information compiled from this research provides design engineers with updated deflection values for various configurations of 31-inch W-beam guardrail under *MASH* impact conditions. These values can be used to determine an appropriate guardrail configuration to use when clearance to a hazard or obstruction behind the rail is less than the design deflection of standard 31-inch W-beam guardrail.

17. Key Words 31-inch Guardrail, W-Beam Guardrail, Blockout, Half-Post Spacing, Quarter-Post Spacing, Full-Post Spacing, Guardrail Deflection, Barrier Deflection, *MASH*, *NHCRP Report 350*, Roadside Safety, BARRIERVII, Computer Simulation	18. Distribution Statement Copyrighted. Not to be copied or reprinted without consent from Washington State DOT.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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CHAPTER 1. INTRODUCTION

INTRODUCTION

The available deflection distance from the face of guardrail to the face of a hazard is an important consideration in the selection and placement of a guardrail system. Maximum deflection values for single and nested W-beam guardrail with a post spacing of 6 ft-3 inches and 3 ft-1½ inches have yet to be updated to reflect the change in guardrail height due to the higher center of gravity for Test Level 3 (TL-3) vehicles specified in American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*).(1) The Fourth Edition of AASHTOS's *Roadside Design Guide*, Table 5-6 ("Summary of Maximum Deflections"), lists values for single (Run No. 1 – 4) and nested (Run No. 5 – 8) W-beam guardrail that were simulated and crash tested using a 27-inch W-beam guardrail.(2) Many states have asked, "can the new 31-inch W-beam guardrail achieve the same performance level and maximum deflection values shown in the Fourth Edition of AASHTO's *Roadside Design Guide*?"

Table 5-6 of Chapter 5 in the AASHTO *Roadside Design Guide* lists deflections for various beam guardrail configurations. The majority of values listed in the table are based on simulations. A limited number have been crash tested using a 4400-lb sedan to support deflection values. BARRIERVII simulation was used to determine dynamic deflections for systems that had not been crash tested.(3)

BARRIERVII is a two-dimensional (2D) finite element analysis program that was developed to simulate the impact behavior of flexible guardrail systems. Since it is a simplified 2D analysis, the software cannot capture snagging, underride of the barrier, override of the barrier, or vehicle stability, but it can reasonably predict the maximum deflection of a stable impact. This analysis package has been used historically on many projects to predict deflection of barrier systems and to predict critical impact locations for full-scale crash tests. The software provides a cost-effective method for simulating a large number of barrier configurations to determine maximum deflection.

BARRIERVII analysis were used to predict deflection for reduced post spacing (up to quarter spacing) for the 31-inch tall W-beam guardrail. MGS tests with the small car have shown significant snagging and yawing with standard post spacing yet met *MASH* performance requirements. Since BARRIERVII is not capable of predicting snagging potential arising from vehicle wheel/suspension interacting with the posts, the results of the reduced ¼ post spacing should be used with caution. For this reason this study only addresses the deflection potential.

Under Pooled Fund Project 405160-24 "Guardrail Deflection Analysis" (referred to hereafter as Phase I), crash test data for W-beam guardrail systems evaluated under National Cooperative Highway Research Program (NCHRP) *Report 350* and AASHTO *MASH* were obtained to synthesize maximum dynamic deflections.(4, 5) This phase only involved gathering available deflection information from recent crash tests, and did not include any additional simulation or testing. This information was valuable in determining what system configurations needed to be simulated under the current Phase II project. The gathered information was also valuable in validating the guardrail model before proceeding with deflection predictions of different configurations.

OBJECTIVE

The purpose of this research effort was to provide an update to the maximum deflection values presented in AASHTOS's *Roadside Design Guide* based on simulations and crash test results for installations of strong post, 31-inch W-beam guardrail systems (AASHTO Task Force 13 Designator SGR47).(6) The research summarizes the results of computer simulations and crash tests to determine maximum deflections for new 31-inch W-beam guardrail barrier systems with W6×8.5 strong posts (SGR47) with varying post spacing (full-post spacing, half-post spacing, and quarter-post spacing) of both single and nested guardrail elements when impacted by the 2270P pickup under TL-3 impact conditions.

Phase I of the research was performed previously to gather the available crash test data on W-beam guardrail systems and is discussed under separate cover. Phase II of the research was focused on simulating additional 31-inch guardrail systems to broaden the range of system configurations for which deflection data is available. This phase fills in the gaps in crash test data by simulating useful configurations using BARRIERVII, a two-dimensional finite element analysis program. These simulations were used to predict the deflection characteristics of specific guardrail configurations. The resulting data was then combined with crash test data to update the Roadside Design Guide barrier deflection guidance table.

The information compiled from this research provides design engineers with updated deflection values for various configurations of 31-inch W-beam guardrail under *MASH* impact conditions. These values can be used to determine an appropriate guardrail configuration to use when clearance to a hazard or obstruction behind the rail is less than the design deflection of standard 31-inch W-beam guardrail.

CHAPTER 2. TASK 1 – MODELING BARRIER SYSTEM USING BARRIERVII

TASK OBJECTIVE

The objective of this task was to perform simulations using BARRIERVII to compare the maximum barrier deflection and the deflected shape of the barrier to actual full-scale crash test data. A Midwest Guardrail System (Update to *NCHRP Report 350* Test No. 3-11 with 28" Vehicle C.G. Height) was used for these simulations and comparisons.(7) This comparison helped validate the guardrail system model.

MIDWEST GUARDRAIL SYSTEM

Details for the simulated W-beam guardrail system were as described in the drawings in the test report.(7) The barrier was 181 ft–3 inches in length and comprised of standard 12-guage W-beam guardrail supported by steel guardrail posts. The system used 29 posts fabricated from ASTM A36 steel W6×8.5 sections. Each post measured 6 ft long and was installed with a center-to-center spacing of 75 inches. Non breakaway cable anchorage systems were used at the ends of the system. The system used in the test is depicted in Figure 1.

BARRIERVII MODELING

To increase the accuracy of the output data from the simulation, the nodes on the guardrail were spaced at 6.25 inches. Appropriate material properties were assigned to the guardrail corresponding to standard 12-guage W-beam. Posts were connected to the corresponding nodes to represent the proper post spacing. Properties for a standard W6×8.5 post were assigned to corresponding line posts. End posts (post no. 1 and 29) were stiffened to account for the anchorage characteristics of the cable anchors used in the actual test. When evaluating pocketing and dynamic deflection performance, the output data was plotted using AutoCAD®. Post stiffness and yield moment were calibrated to obtain system deflections comparable to the actual full-scale crash test. A sensitivity analysis was performed by varying the stiffness and yield moments of the posts to better understand system behavior. The simulation iterations and their corresponding results are shown in Tables 1 and 2 and Figure 2.

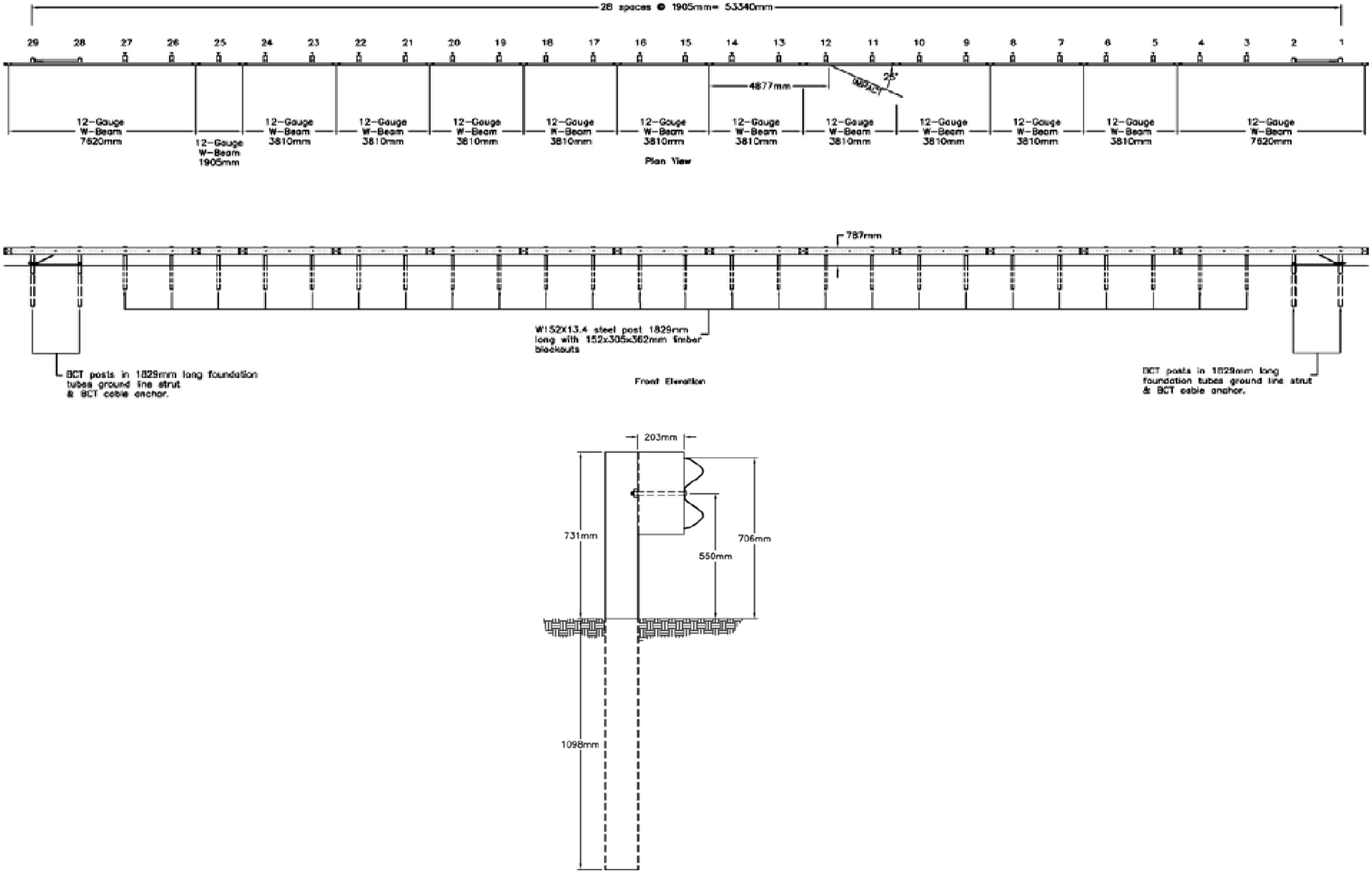
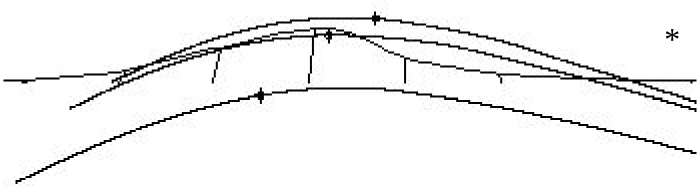


Figure 1. Midwest Guardrail System as Tested. (7)

Table 1. Stiffness Parameters.

Iteration #	Stiffness Parameters (kips, inch)							
	Intermediate Posts				End Posts			
	Strong axis Stiffness (kip/inch)	Weak axis Stiffness (kip/inch)	Base moment about strong axis (kip-inch)	Base moment about weak axis (kip-inch)	Strong axis Stiffness (kip/inch)	Weak axis Stiffness (kip/inch)	Base moment about strong axis (kip-inch)	Base moment about weak axis (kip-inch)
1	0.79	3.61	77.7	361.4	1500	1500	10000	10000
2	0.79	3.61	77.7	361.4	10	10	10000	10000
3	0.79	3.61	77.7	361.4	1500	1500	747	10000
4	0.79	3.61	77.7	280.4	1500	1500	547	10000

Table 2. Iteration Results.

ITERATION #	RESULTS
1	• The maximum deflection of the barrier was lower than in the actual test. • The barrier deflected shape from AutoCAD® plots did not match with the actual deflected shape of the barrier.
2	• Changing the stiffness about both axes of the end posts did not make any significant changes in the overall deflection characteristics of the barrier.
3	• Lowering the yield moment about the strong axis of the end posts increased the maximum deflection of the barrier to a comparable value. • However, there was evidence of pocketing of the vehicle in the AutoCAD® plots as shown:  [*] • To acheive better correlation of the deflected barrier shape, the yield moments of the intermediate posts were reduced to allow the posts to yield sooner, which resulted in a smoother deflected barrier shape during redirection of the vehicle.
4	• With the reduced value for post yield moment about the weak axis, the maximum barrier deflection and the deflected shape adequately matched the crash test data.

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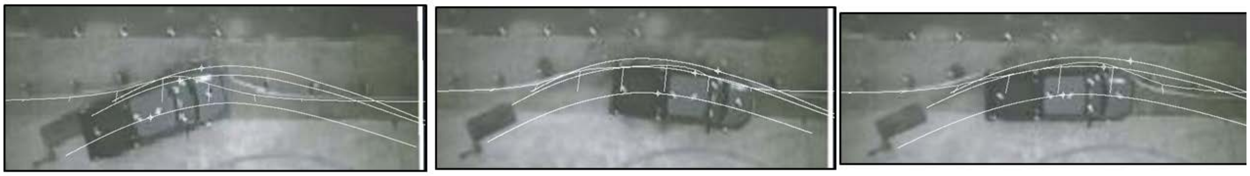
[*] The wavy curve is the barrier. Bottom curve is the CG of the vehicle, top curve is the front corner of the vehicle, and middle curve is the center of the driver side tire.



$T_{AUTOCAD} = 0.142$
$T_{TEST} = 0.142$

$T_{AUTOCAD} = 0.264$
$T_{TEST} = 0.264$

$T_{AUTOCAD} = 0.342$
$T_{TEST} = 0.342$

$T_{AUTOCAD} = 0.182$
$T_{TEST} = 0.142$

$T_{AUTOCAD} = 0.308$
$T_{TEST} = 0.264$

$T_{AUTOCAD} = 0.402$
$T_{TEST} = 0.342$

Figure 2. Final Comparison of Results with Actual Test:

CHAPTER 3. TASK 2 – BARRIERVII ANALYSIS FOR SINGLE W-BEAM GUARDRAIL SYSTEM

TASK OBJECTIVE

The objective of this task was to find the critical impact point (CIP) that produces the maximum deflection for the single W-beam guardrail. Additionally, the researchers reviewed the simulated impact performance of the W-beam guardrail system.

ANALYSIS TO FIND CRITICAL IMPACT LOCATION

The previous calibration simulation used the same impact location used in the full-scale crash test to permit direct comparison of deflection results. In this task, a sensitivity analysis was performed using BARRIERVII to find the impact location that produced the maximum overall barrier deflection for the guardrail system. The impact location was varied in 6 inch increments upstream and downstream from the initial impact location used in the test. For each iteration, a BARRIERVII simulation was performed to find the maximum barrier deflection. The impact location that produced the highest maximum deflection value was chosen as the CIP for the system.

Posts 11 and 12 were located 787.5 inches and 862.5 inches downstream of the upstream end terminal, respectively. The test impact point was 858 inches downstream of the upstream end terminal as shown in Figure 3. The sensitivity analysis to find the CIP was performed in 6-inch increments between posts 11 and 12 starting from the impact point used in the actual test (858 inches). Figure 4 shows the results of the analysis. The resulting CIP was 828 inches downstream of the upstream end anchor and resulted in a dynamic deflection of 48 inches.

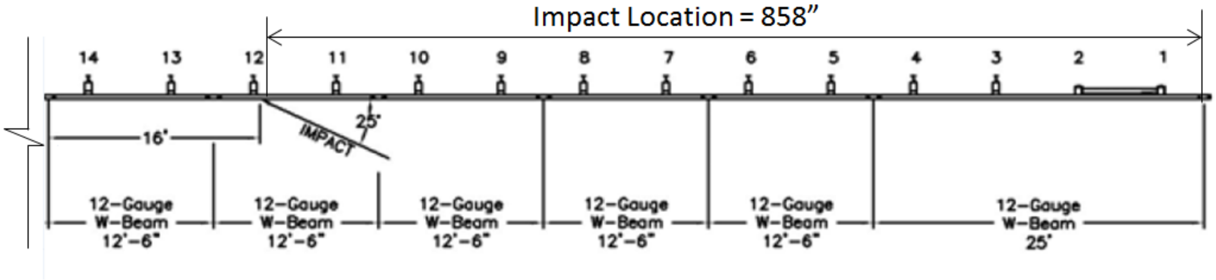
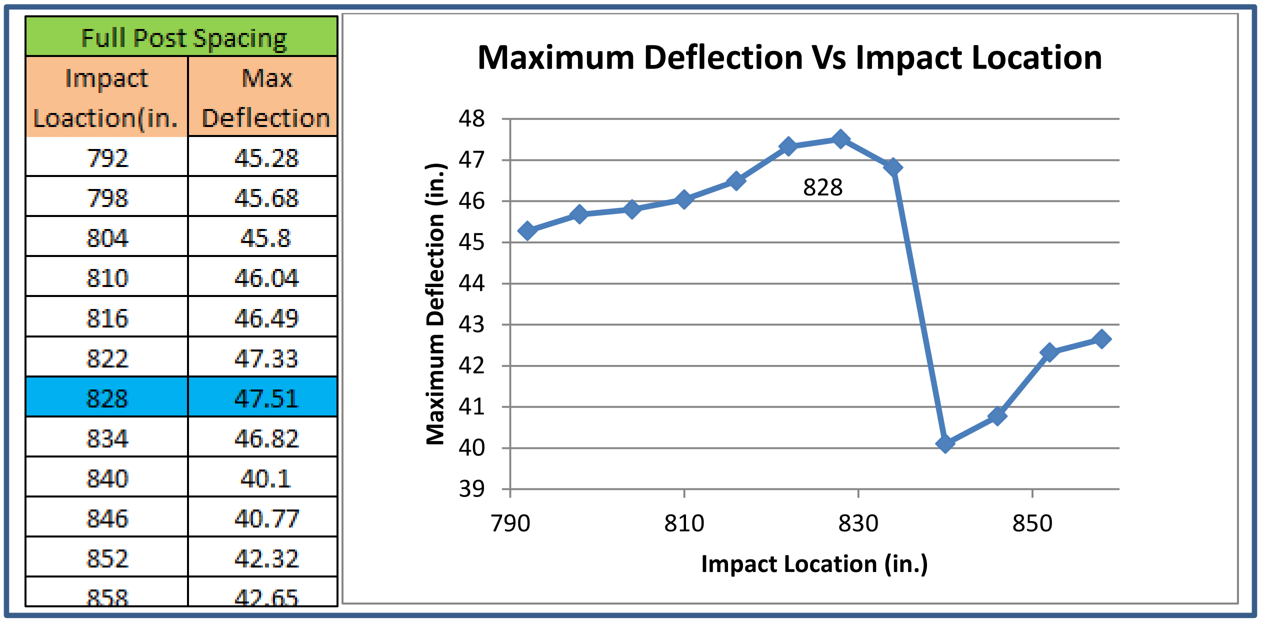


Figure 3. CIP for Single W-Beam Guardrail System at Full-Post Spacing.



Full Post Spacing	
Impact Loaction(in.	Max Deflection
792	45.28
798	45.68
804	45.8
810	46.04
816	46.49
822	47.33
828	47.51
834	46.82
840	40.1
846	40.77
852	42.32
858	42.65

Figure 4. Determination of Maximum Deflection for Single W-Beam Guardrail System at Full-Post Spacing.

SIMULATION RESULTS FOR CRITICAL IMPACT LOCATION IN BARRIERVII

The results of the BARRIERVII simulation at the CIP were further analyzed. The analysis focused on determining the maximum deflection in the guardrail and its deflection characteristics. Using a program developed in Visual Basic, data from the BARRIERVII simulations were plotted graphically using AutoCAD®, as shown in Figure 5. These plots included the deflected shape of the barrier, vehicle tire paths, and simulated vehicle nodes. This provided a visual representation of the results and made it easier to evaluate potential for vehicle pocketing or snagging. It also helped in understanding the deflection characteristics of the guardrail. The simulation indicated a smooth redirection and a predicted maximum deflection of 48 inches. Three curves are plotted on the image that correspond to a different part of the simulated impacting vehicle. The top curve represents the trajectory of the driver side front corner of the vehicle. The second curve represents the trajectory of the center of the driver side front tire of the simulated impacting vehicle. The third curve represents the trajectory of the center of gravity (CG) of the simulated impacting vehicle.

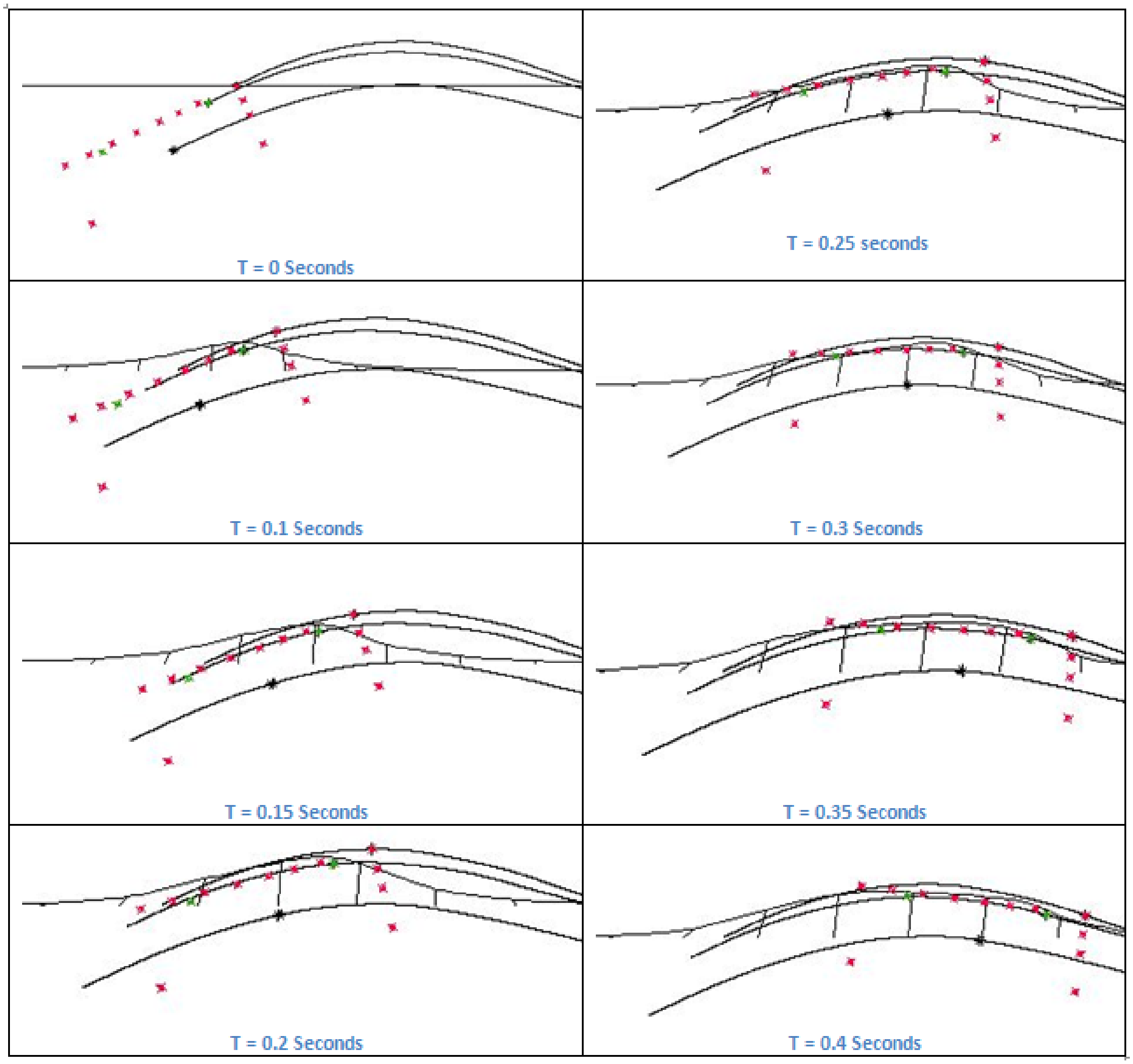


Figure 5. Sequential Images of Impact with Single W-Beam Guardrail System at Full-Post Spacing.

CHAPTER 4. TASK 3 –MAXIMUM DEFLECTION OF SINGLE W-BEAM GUARDRAIL AT HALF-POST SPACING AND QUARTER-POST SPACING

TASK OBJECTIVE

The objective of this task was to perform BARRIERVII simulations under *MASH* Test 3-11 impact conditions to determine the maximum deflections for the single W-beam guardrail system at half-post and quarter-post spacing. The goal was to study the difference in the deflection characteristics of the guardrail when the system was stiffened by decreasing the post spacing.

HALF-POST SPACING

Determination of CIP and Maximum Deflection

The post spacing for the guardrail system model was changed from 75 inches to 37.5 inches. This resulted in a more stiffened system compared to the 75-inch full-post spacing system. Analyses were performed for this system using BARRIERVII to find the CIP based on the maximum deflection criteria. For the half-post spacing, the impact location was moved in 6-inch increments, starting 828 inches downstream of the upstream barrier end anchor. Figure 6 shows the results of the analysis for the half-post spacing system. The resulting CIP was 852 inches downstream of the upstream end anchor and dynamic deflection at this location was 29 inches.

Half Post Spacing	
Impact Loaction(in.	Max Deflection
828	27.24
834	28.19
840	28.36
846	28.86
852	28.96
858	26.44

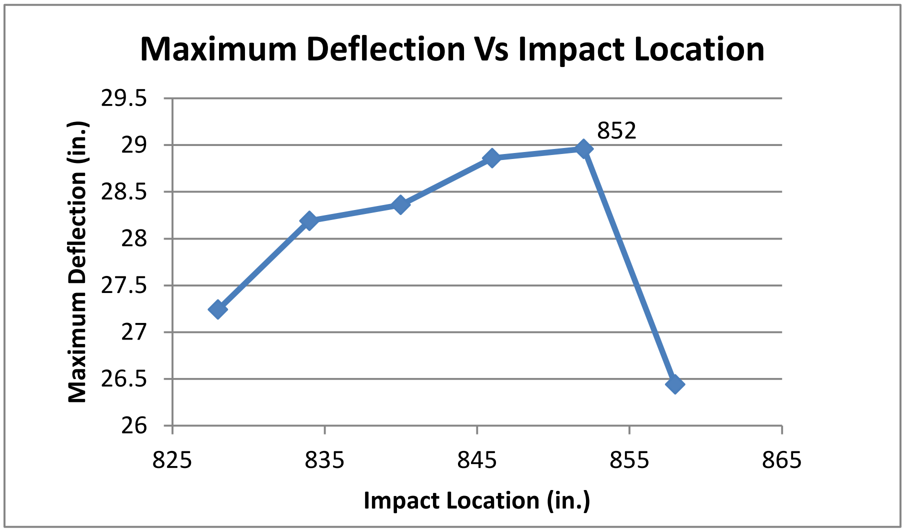


Figure 6. Analysis for Single W-Beam Guardrail System at Half-Post Spacing.

Deflected Barrier Shape at CIP

The BARRIERVII simulation of the guardrail system with half-post spacing impacted at the CIP was then further analyzed. The analysis focused on the deflection characteristics of the deformed guardrail. Using a program developed in Visual Basic, the data from the simulation was plotted using AutoCAD®, as shown in Figure 7. The simulation indicated smooth redirection and a predicted maximum deflection of 29 inches.

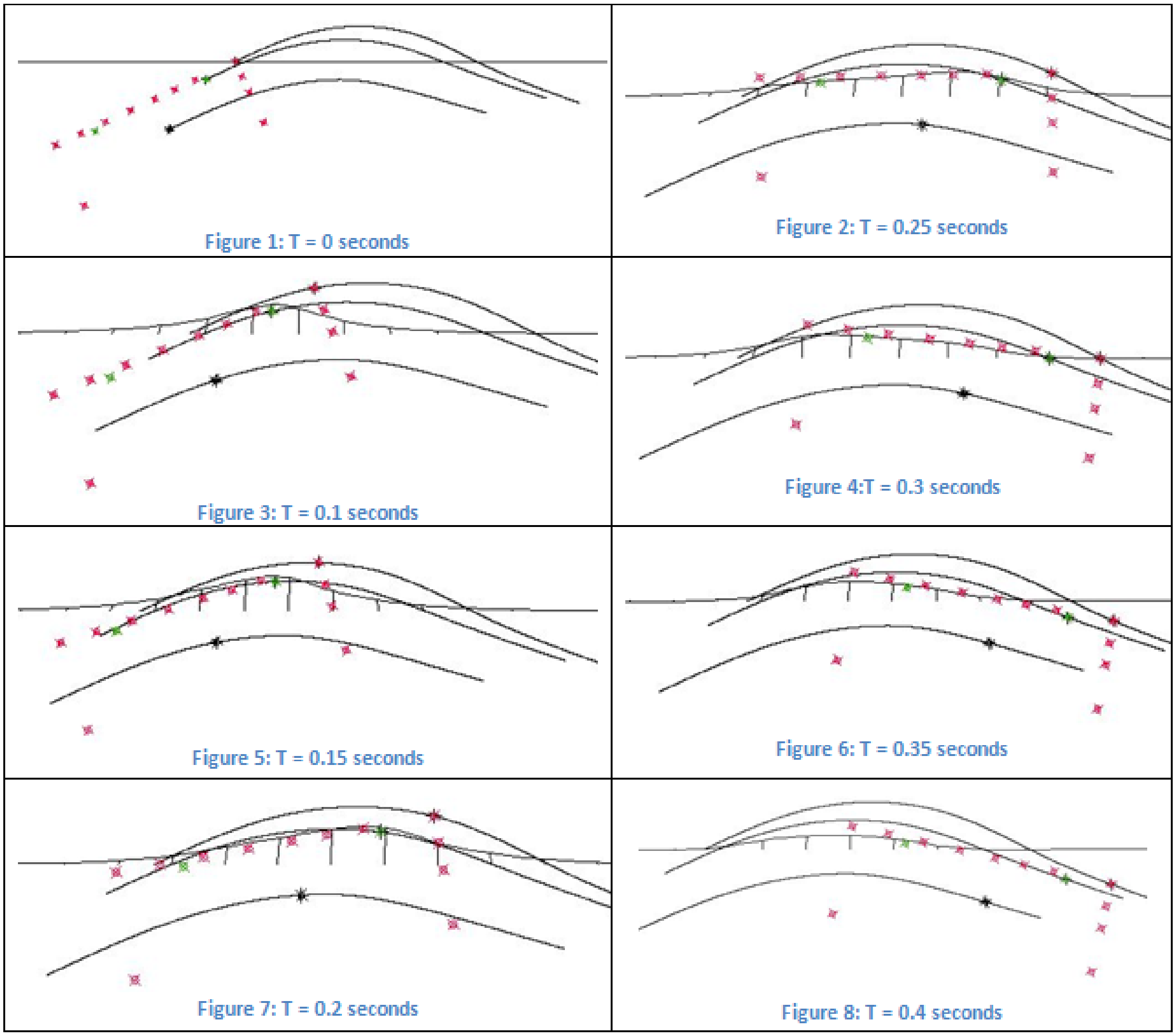


Figure 1: T = 0 seconds

Figure 2: T = 0.25 seconds

Figure 3: T = 0.1 seconds

Figure 4:T = 0.3 seconds

Figure 5: T = 0.15 seconds

Figure 6: T = 0.35 seconds

Figure 7: T = 0.2 seconds

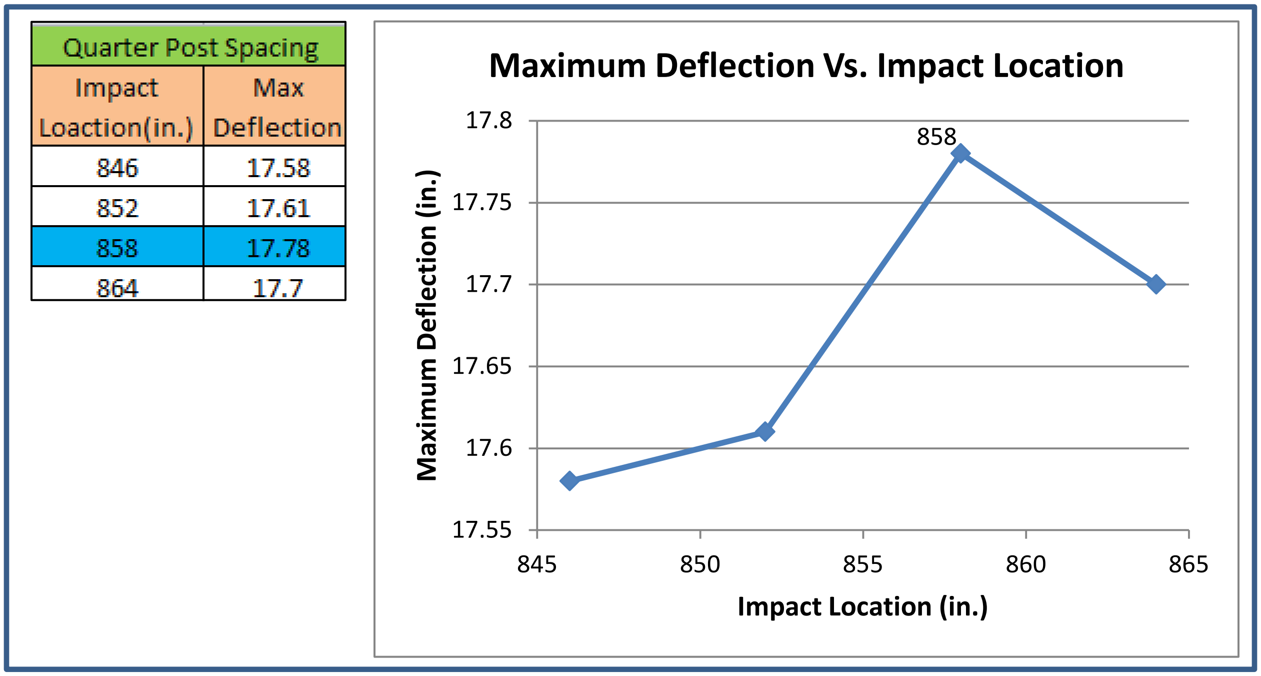
Figure 8: T = 0.4 seconds

Figure 7. Sequential Images of Impact with Single W-Beam Guardrail System at Half-Post Spacing.

QUARTER-POST SPACING

Determination of CIP and Maximum Deflection

The post spacing for the guardrail system was changed from 37.5 inches to 18.75 inches. This further stiffened the system compared to the 37.5-inch half-post spacing system. Analyses were performed for this system using BARRIERVII to identify the CIP based on the maximum deflection criteria. The impact point was moved in 6-inch increments from 843.75 inches downstream of the upstream end anchor. Figure 8 shows the results of the analysis for quarter-post spacing system. The resulting CIP was 858 inches downstream of the upstream end anchor, and the corresponding maximum dynamic deflection at this location was 18 inches.



Quarter Post Spacing	
Impact Loaction(in.)	Max Deflection
846	17.58
852	17.61
858	17.78
864	17.7

Figure 8. Analysis for Single W-Beam Guardrail System at Quarter-Post Spacing.

Deflected Barrier Shape at CIP

The BARRIERVII simulation of the guardrail system with quarter-post spacing impacted at the CIP was then further analyzed. The analysis focused on the deflection characteristics of the guardrail. Data from the simulation was plotted using AutoCAD®, as shown in Figure 9. The simulation indicated smooth redirection and a predicted maximum deflection of 18 inches.

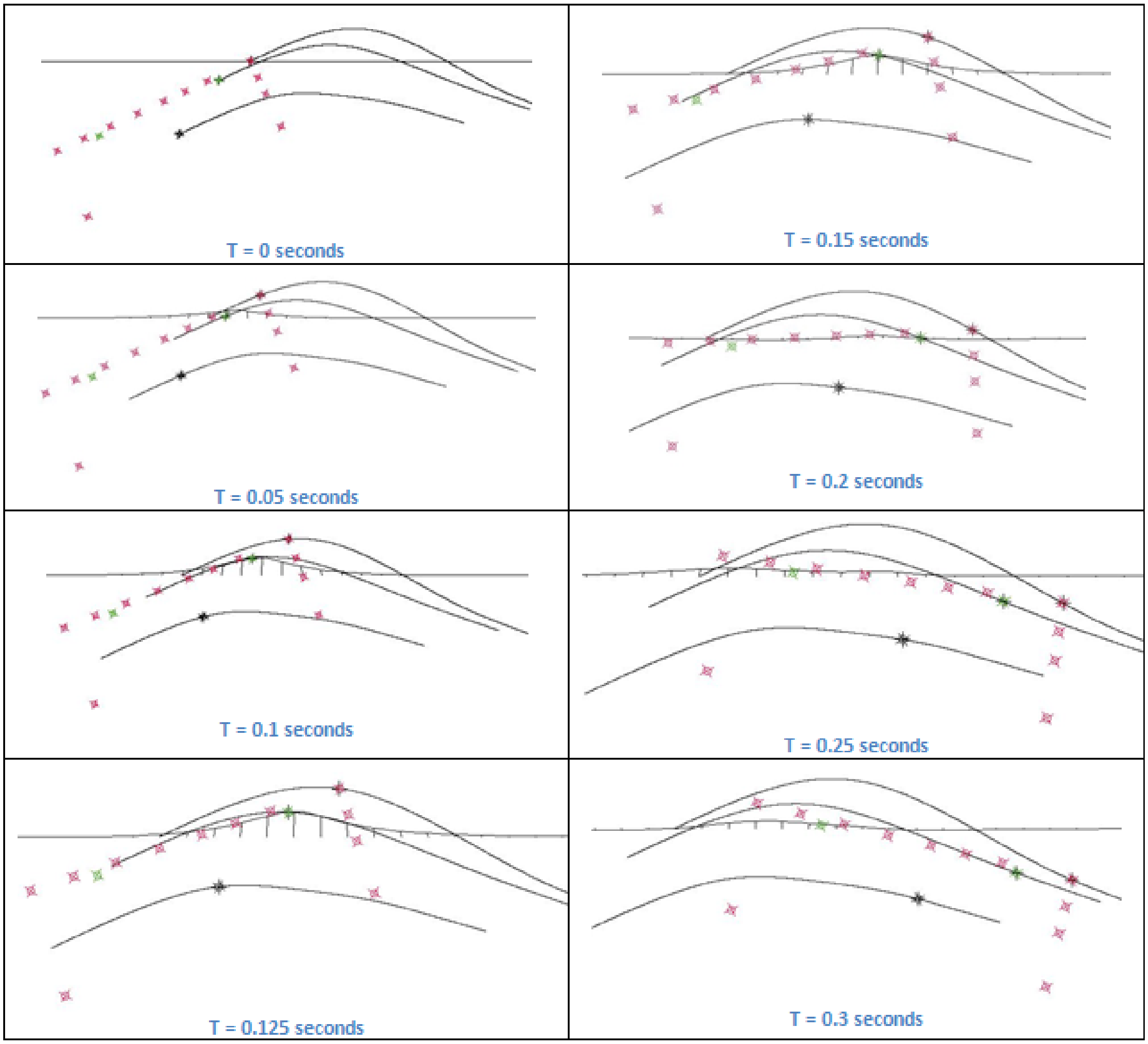


Figure 9. Sequential Images of Impact with Single W-Beam Guardrail System at Quarter-Post Spacing.

SUMMARY AND CONCLUSIONS FOR SINGLE W-BEAM GUARDRAIL SYSTEM

The results of the BARRIERVII simulation analyses for the single W-beam guardrail system are summarized in Table 3. This summary table indicates the respective CIP and maximum predicted deflection.

Table 3. Results for Single W-Beam Guardrail System.

Strong Post W-beam Guardrail		
Post Spacing	Impact Location Downstream of Upstream End Anchor (inches)	Maximum Barrier Deflection (inches)
Full (Test)	858	44
Full (CIP)	828	48
Half (CIP)	852	29
Quarter (CIP)	858	18

CHAPTER 5. TASK 4 – MAXIMUM DEFLECTION OF NESTED W-BEAM GUARDRAIL

TASK OBJECTIVE

The objective of this task was to perform BARRIERVII simulations under *MASH* Test 3-11 impact conditions to determine the maximum dynamic deflections for a nested W-beam guardrail system at full-post, half-post, and quarter-post spacing. The goal was to study the deflection characteristics of the guardrail system by changing the previously calibrated single W-beam BARRIERVII barrier model to represent a nested W- beam barrier model. The procedure to determine the CIP and maximum deflection was similar to the procedure used to evaluate the single W-beam guardrail system. The analyses and results are discussed below.

FULL-POST SPACING

Determination of CIP and Maximum Deflection

To determine the CIP, simulation analyses were performed using BARRIERVII to determine the impact location that resulted in the maximum barrier deflection. The impact location was iterated in 6-inch increments upstream and downstream from the impact location used in the full-scale crash test discussed in previous sections (full-post spacing with single W-beam guardrail). For each iteration, a BARRIERVII simulation was performed to find the maximum barrier deflection. The impact location that gave the highest maximum deflection value was chosen as the CIP for the system. Figure 10 shows the results of the analysis for a nested W-beam guardrail system with full-post spacing. The resulting CIP was 828 inches downstream of the upstream end anchor and the dynamic deflection at this location was 46 inches.

Full Post Spacing	
Impact Loaction(in.)	Max Deflection
792	41.73
798	42.5
804	43.24
810	44.36
816	45.08
822	45.78
828	46.29
834	46.13
840	45.96
846	39.21
852	39.31
858	39.35

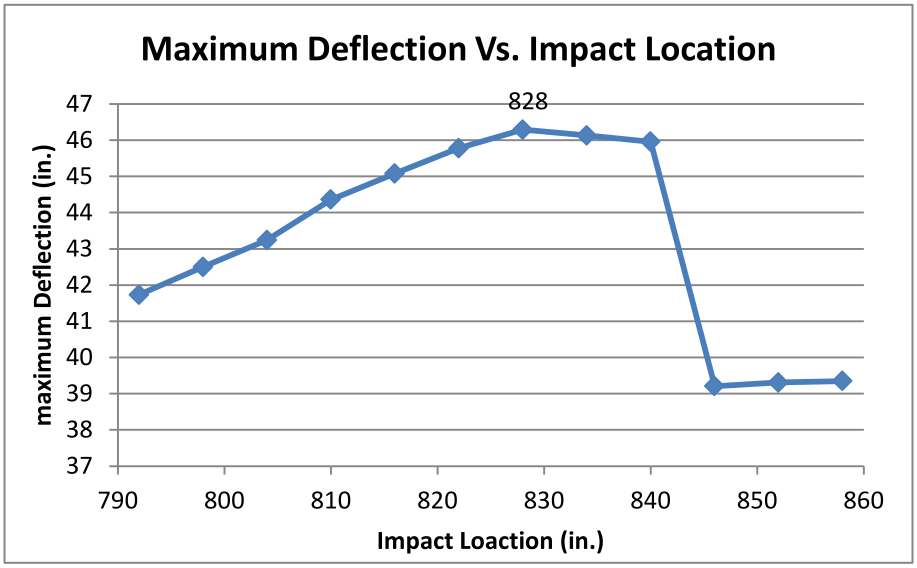
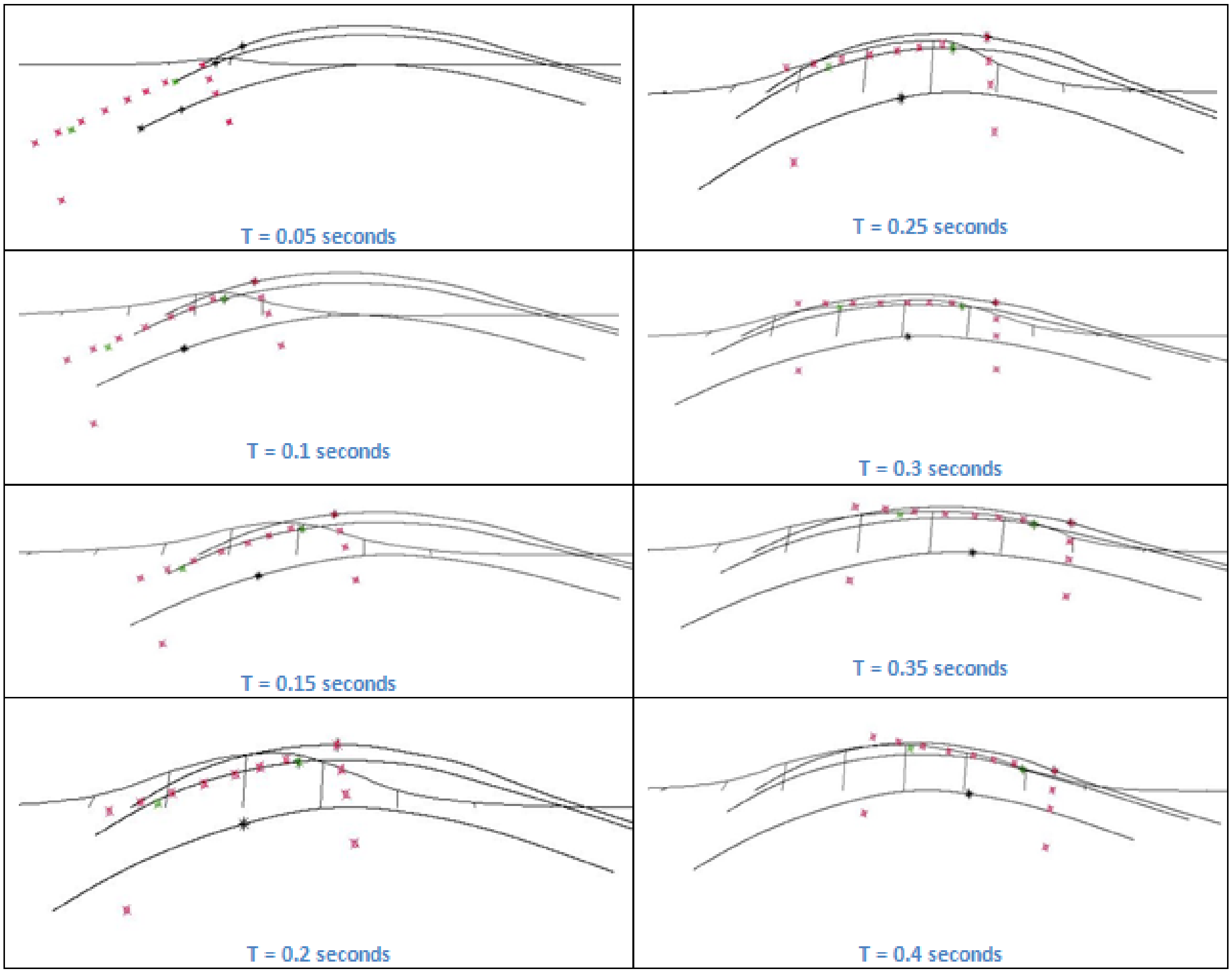


Figure 10. Determination of Maximum Deflection for Nested W-Beam Guardrail System at Full-Post Spacing.

Deflected Barrier Shape at CIP

BARRIERVII simulation of a nested W-beam guardrail with full-post spacing impacted at the CIP was further analyzed. The analysis focused on the deflection characteristics of the deformed guardrail during the impact. Data from the simulation was plotted using AutoCAD®, as shown in Figure 11. The simulation indicated smooth redirection and a predicted maximum deflection of 46 inches.



T = 0.05 seconds

T = 0.25 seconds

T = 0.1 seconds

T = 0.3 seconds

T = 0.15 seconds

T = 0.35 seconds

T = 0.2 seconds

T = 0.4 seconds

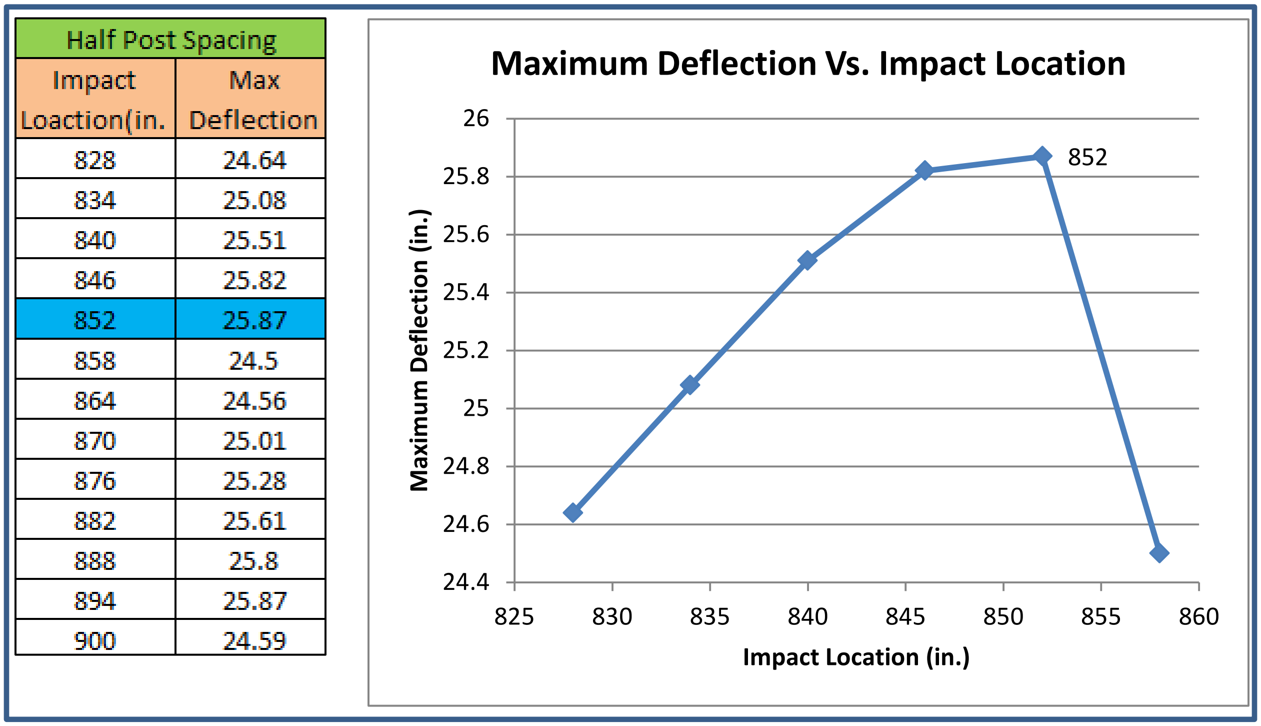
Figure 11. Sequential Images of Impact with Nested W-Beam Guardrail System at Full-Post Spacing.

HALF-POST SPACING

Determination of CIP and Maximum Deflection

The post spacing of the nested W-beam guardrail system model was changed from 75 inches to 37.5 inches. This increased the stiffness of the system compared to the 75-inch full-post spacing system. Simulation analyses were performed for this system using BARRIERVII to find the CIP based on the maximum deflection criteria. The impact location was moved in

6-inch increments from 828 inches downstream of the upstream transition. Figure 12 shows the results of the deflection analysis for the half-post spacing nested W-beam guardrail system. The resulting CIP was 852 inches downstream of the upstream end anchor and the dynamic deflection at this location was 26 inches.



Half Post Spacing	
Impact Loaction(in.	Max Deflection
828	24.64
834	25.08
840	25.51
846	25.82
852	25.87
858	24.5
864	24.56
870	25.01
876	25.28
882	25.61
888	25.8
894	25.87
900	24.59

Figure 12. Analysis for Maximum Deflection of Nested W-Beam System at Half-Post Spacing.

Deflected Barrier Shape at CIP

BARRIERVII simulation of a nested W-beam guardrail with half-post spacing impacted at the CIP was further analyzed. The analysis focused on the deflection characteristics of the deformed guardrail during impact. Data from the simulation was plotted using AutoCAD®, as shown in Figure 13. The simulation indicated smooth redirection and a predicted maximum deflection of 26 inches.

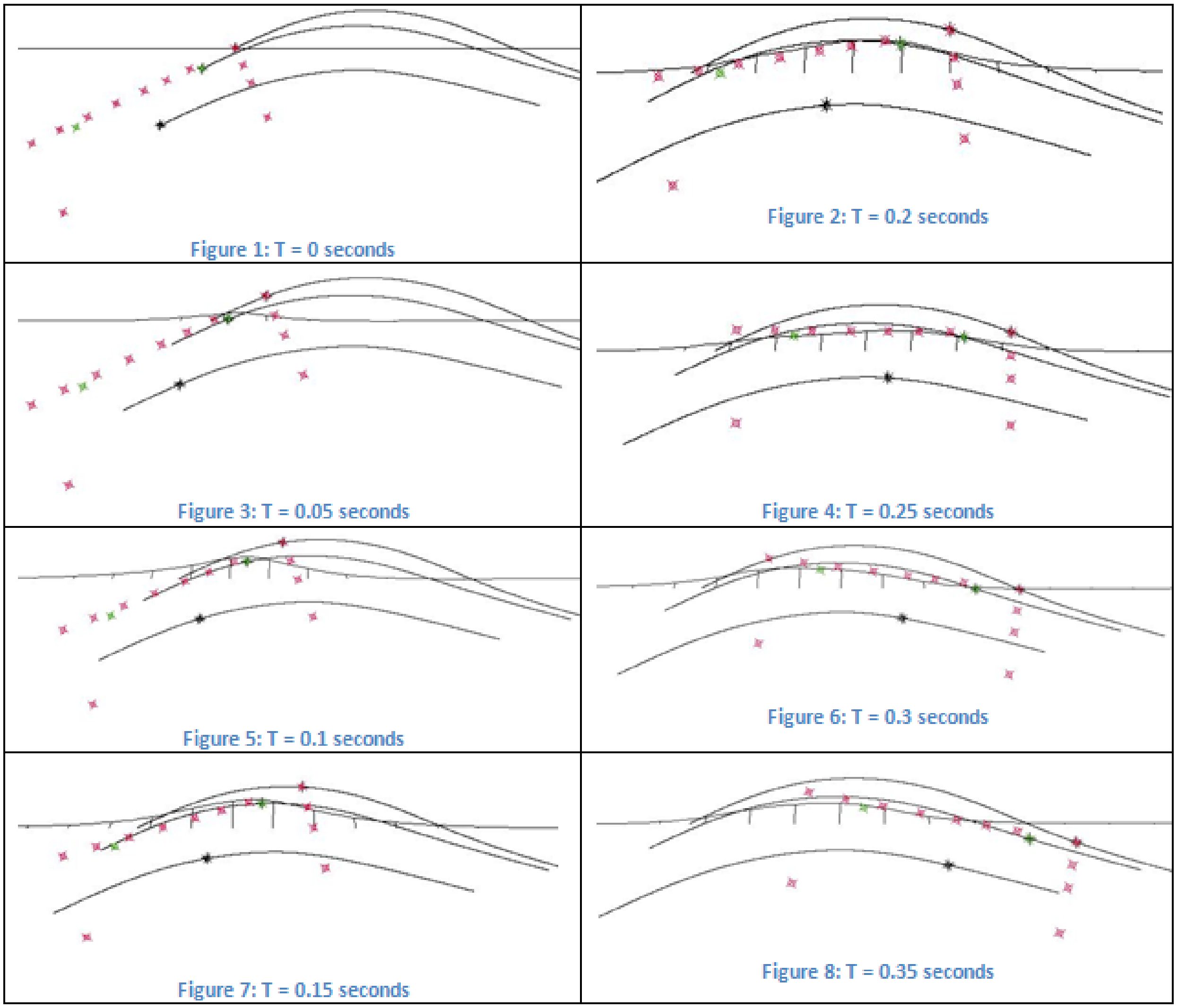


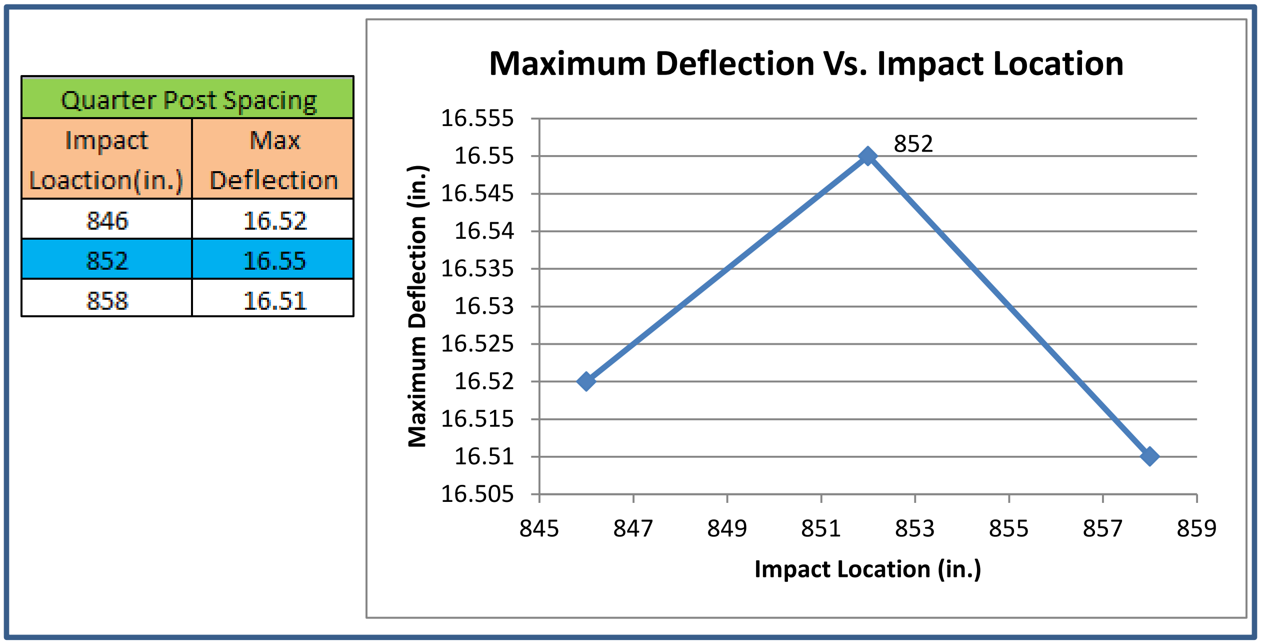
Figure 1: T = 0 seconds
Figure 2: T = 0.2 seconds
Figure 3: T = 0.05 seconds
Figure 4: T = 0.25 seconds
Figure 5: T = 0.1 seconds
Figure 6: T = 0.3 seconds
Figure 7: T = 0.15 seconds
Figure 8: T = 0.35 seconds

Figure 13. Sequential Images of Impact with Nested W-Beam Guardrail System at Half-Post Spacing.

QUARTER-POST SPACING

Determination of CIP and Maximum Deflection

The post spacing of the nested W-beam guardrail system model was changed from 37.5 inches to 18.75 inches, which further stiffened the system compared to the 37.5-inch half-post spacing system. Simulation analyses were performed for this system using BARRIERVII to identify the CIP based on the maximum deflection criteria. The impact location was moved in 6-inch increments from 846 inches downstream of the upstream end anchor. Figure 14 shows the results of the deflection analysis for quarter-post spacing nested W-beam system. The resulting CIP was 852 inches downstream of the upstream end anchor and the corresponding dynamic deflection was 17 inches.



Quarter Post Spacing	
Impact Loaction(in.)	Max Deflection
846	16.52
852	16.55
858	16.51

Figure 14. Analysis for Maximum Deflection of Nested W-Beam System at Quarter-Post Spacing.

Deflected Barrier Shape at CIP

BARRIERVII simulation of a nested W-beam guardrail with quarter-post spacing impacted at the CIP was further analyzed. The analysis focused on the deflection characteristics of the deformed guardrail during impact. Data from the simulation was plotted using AutoCAD®, as shown in Figure 15. The simulation indicated smooth redirection and a predicted maximum deflection of 17 inches.

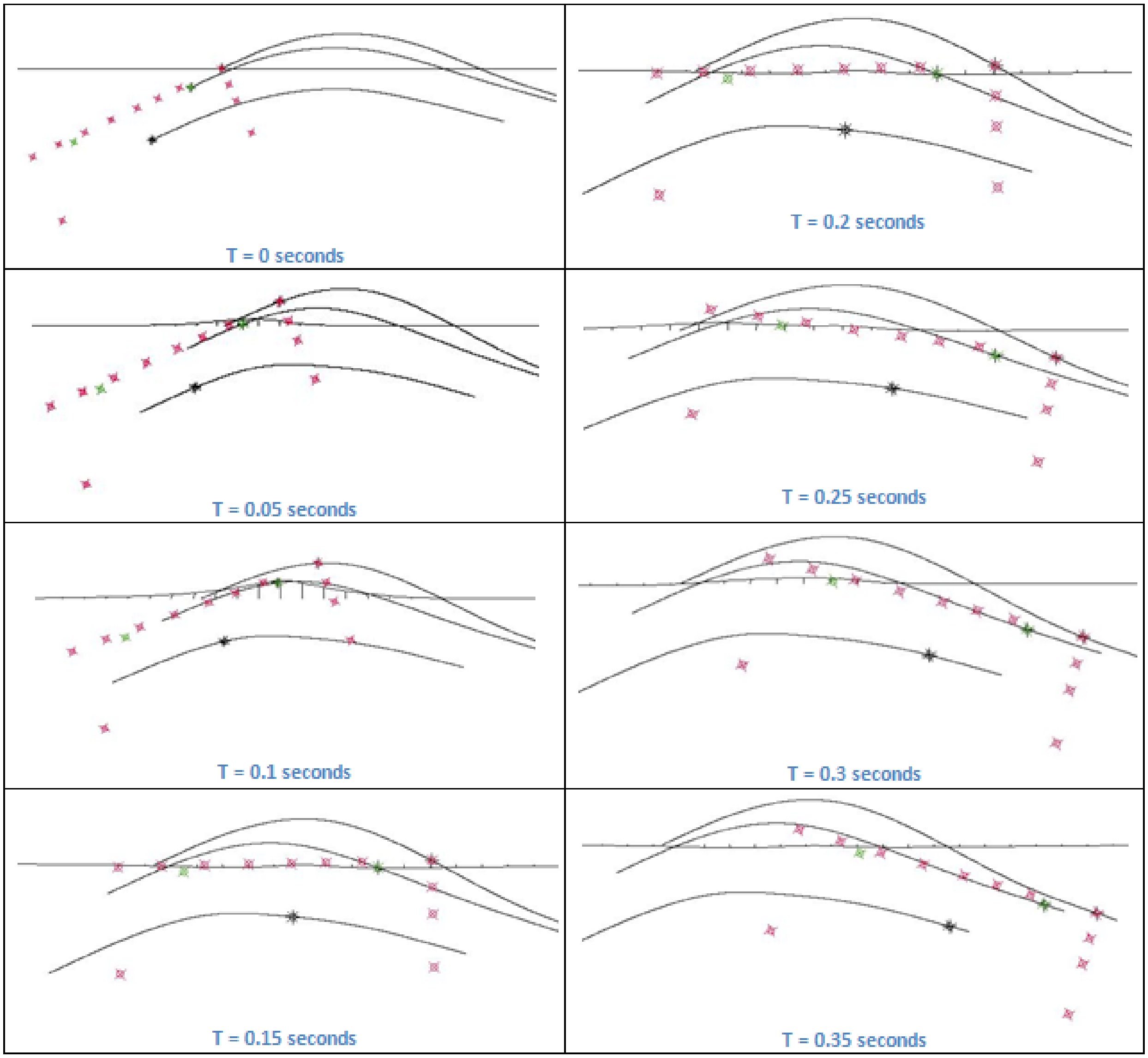


Figure 15. Sequential Images of Impact with Nested W-Beam Guardrail System at Quarter-Post Spacing.

SUMMARY AND CONCLUSIONS FOR NESTED W-BEAM GUARDRAIL SYSTEM

The results of the BARRIERVII simulation study for the nested W-beam guardrail system are summarized in Table 4. Table 4 indicates the respective CIP, maximum predicted deflection, and if pocketing behavior was observed.

Table 4. Results for Single W-Beam Guardrail System.

Strong Post Nested W-beam Guardrail		
Post Spacing	Impact Location Downstream of Upstream End Anchor (inches)	Maximum Barrier Deflection (inches)
Full (CIP)	828	46
Half (CIP)	852	26
Quarter (CIP)	852	17

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