



**VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY**

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Structural Engineering and Materials

**TESTS OF THE JVI SHOOTER IN
DOUBLE-TEE BEAMS**

by
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Submitted to:

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Introduction

In December 2008 four tests were performed on the beam to spandrel connection referred to as a shooter. Two different shooters were tested, a 40 kip capacity shooter and a 50 kip capacity shooter. For each size shooter, two different reinforcing steel designs were investigated. The two design methods are referred to as the Jason and the Norway design methods. A double-tee, 20 ft in length and 10 ft in width was tested. Each stem of the double-tee contained one of the shooter and cage designs. Each test performed had the same set up.

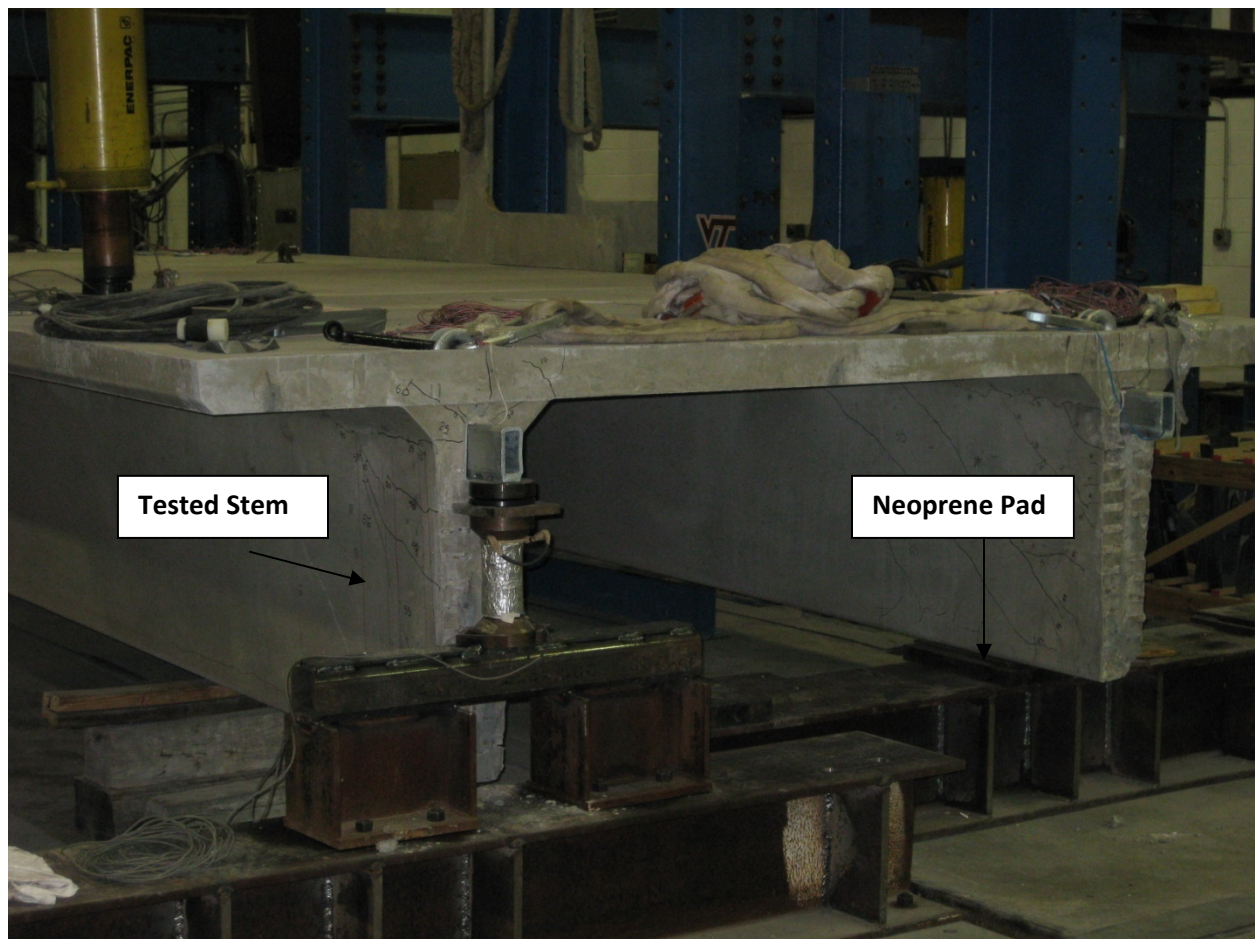


Figure 1: Test Set-up

The double-tee was set up such that three stems were supported on neoprene pads, and the tested stem was supported by the shooter. An actuator was placed 6 ft away from the face of the double-tee, using a load cell to measure the force applied to the beam. Another load cell was placed under the extended arm of the shooter to measure the force carried by the connection. There were also three wire pots set up to measure deflections of the beam. One wire pot was set up under the applied load while two others were set up near the face of the double-tee, one under the stem and the other on the flange of the beam. This was done to make sure there was no separation between the connection and the concrete during testing. Prior to casting of the double-tee, strain gages were placed on the rebar cages to determine how the bars were being engaged during testing.

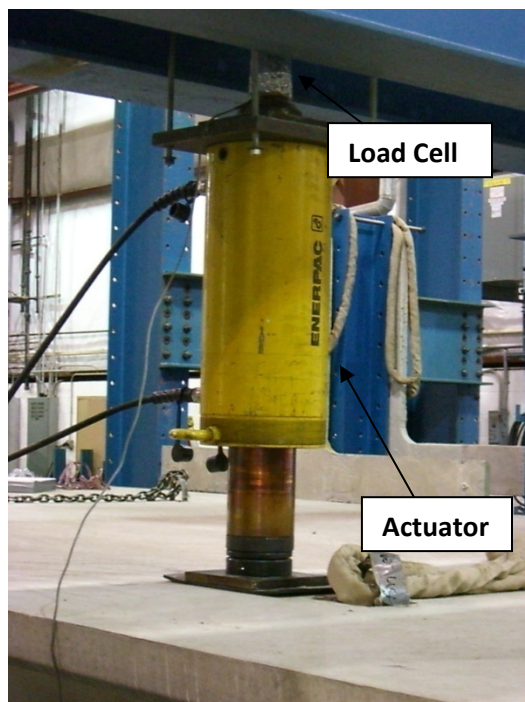


Figure 2: Applied Load

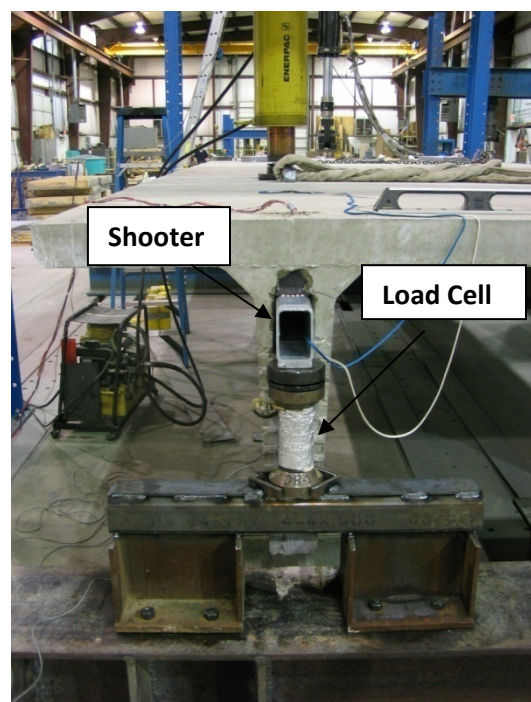
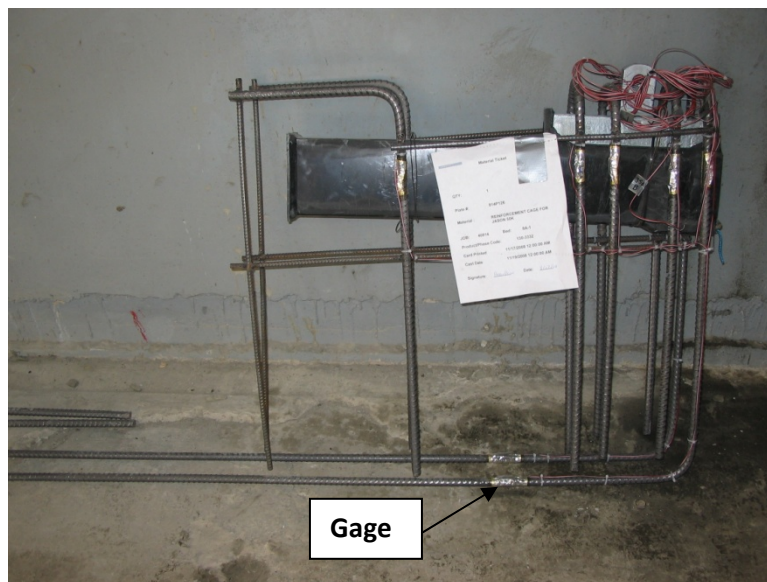
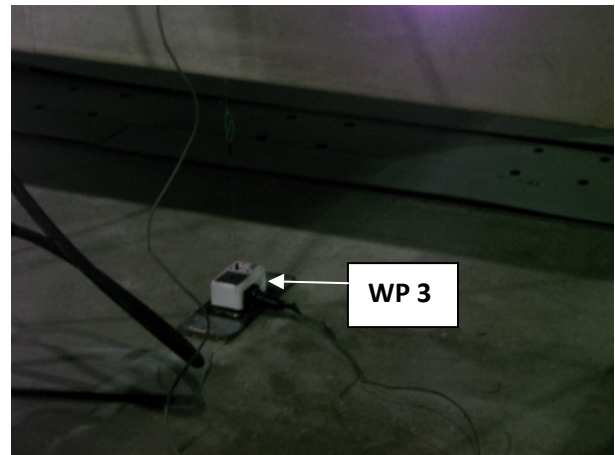
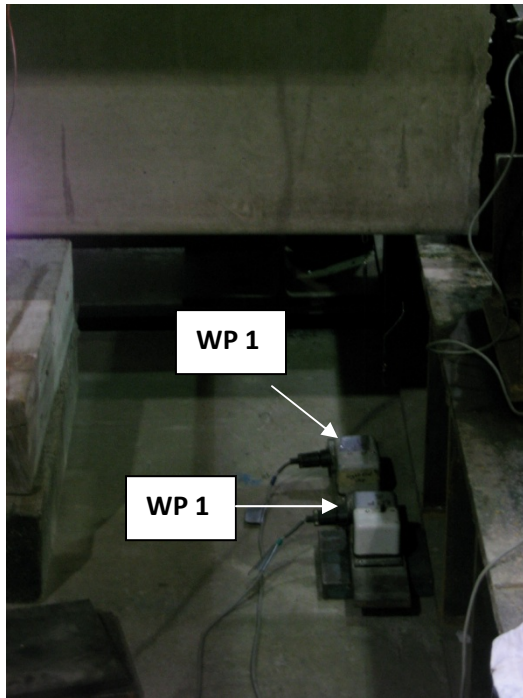


Figure 3: Tested End



The purpose of the tests was to ensure that the shooter capacity was at least achieved and that the rebar cages designed were sufficient to carry this load. Failure of the system was measured when load in the shooter dropped suddenly. The following chart displays the results found after testing.

Table 1: Results

Test	Failure Load (kips)
Norway 50 kip (N50)	50.3
Jason 50 kip (J50)	51.4
Norway 40 kip (N40)	55.3
Jason 40 kips (J50)	61.3

Norway 50 kip Shooter Test

The first test performed was on the Norway 50 kip Shooter. All instrumentation was zeroed while the shooter was not resting on the beam. This was done to determine the self weight that was carried by the shooter. Loading proceeded until 15 kips was registered in the load cell under the shooter, followed by additional increments of 5 kips until failure. After each increment of loading cracks were marked and then monitored to see how much, if any, they opened. This shooter failed at 50.3 kips. On the way to failure, a large crack occurred at 48 kips. This crack was a good indication that failure was near.

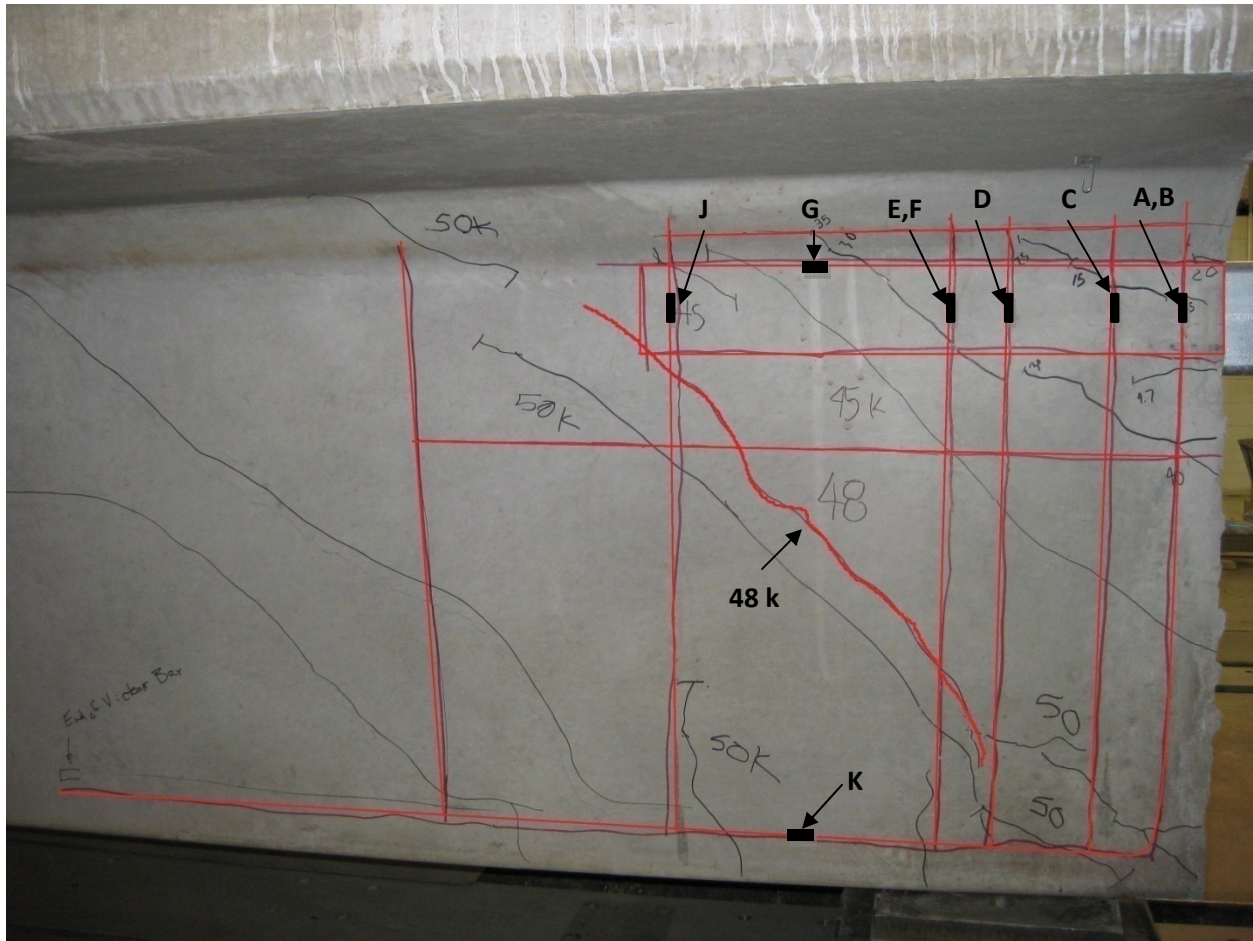


Figure 7: N50 test

The strain in the rebar was measured at several locations labeled with letters A thru K in Figure 7. Figure 8 shows the relationship between the load in the shooter and the strain in each gage. The graph indicates that gages closer to the double-tee end experienced higher strains during testing. This graph shows that the bars farther from the face of the double-tee also experience some tension during the early loading stages. The lower Victor bars, gage K, are not engaged until the concrete cracks across the bar at 48 kips. The Victor bars are the longitudinal bars at the bottom of the rebar cage. The bar sizes and layout are presented in the shop drawings provided by Unistress located in Appendix A.

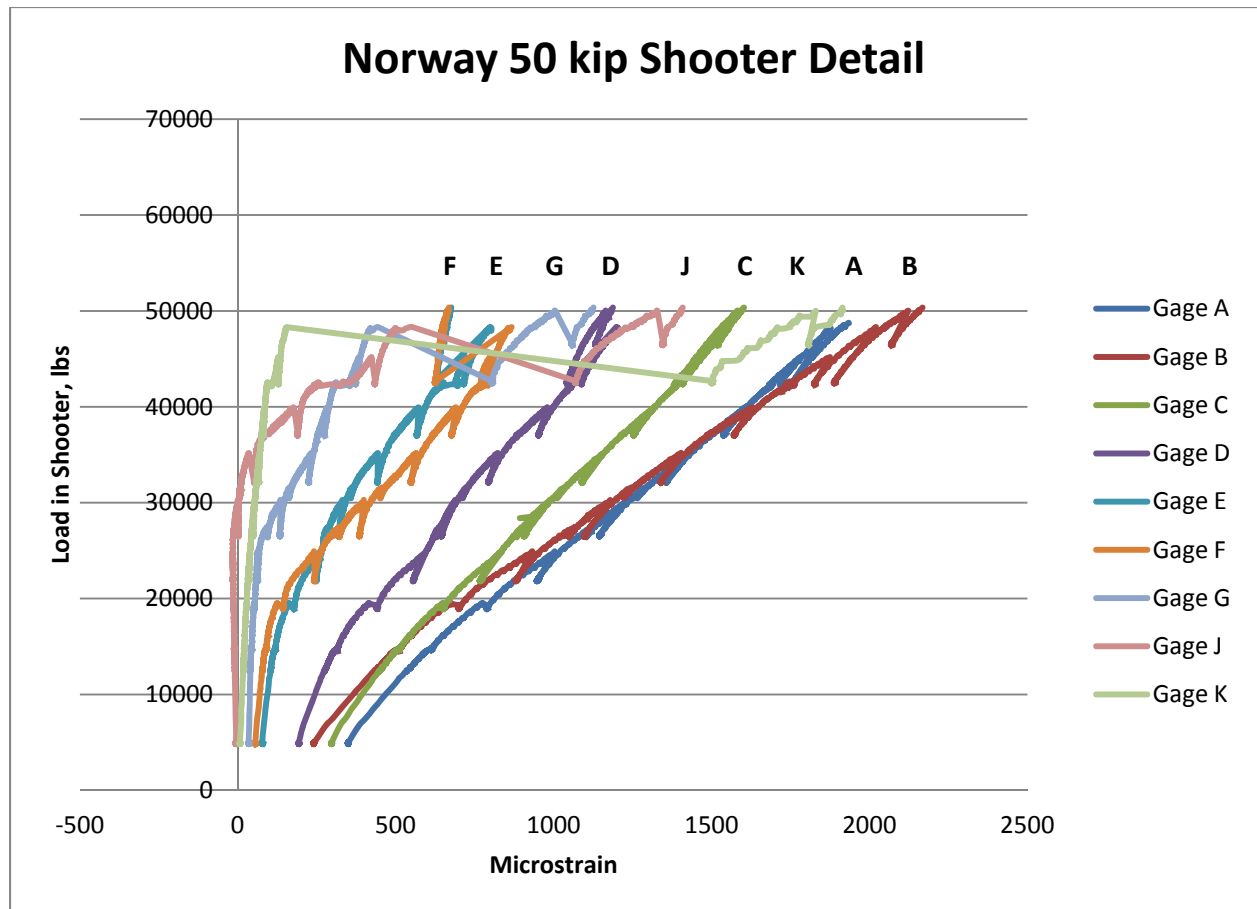


Figure 8: Load vs. Strain for all gages in N50 Test

The next graphs plot the strain in the rebar versus the distance from the face of the double-tee, the force in the front bars versus the load in the shooter, and the displacements of the three wire pots versus the load in the shooter. Figure 9 indicates that as the distance from the face of the double-tee increases, the strain in each gage decreases approximately linearly at each load step represented. Figure 10 indicates that the force resisted by the shooter is linearly related to the force in the first four bars of the cage. In previous calculations using a strut-and-tie model to determine the amount of reinforcing, it was estimated that the force in this region would be lower. This indicates that the model requires adjustment. In Figure 11 the displacements plotted for the three different wire pots are similar and can be considered equivalent. This indicates that the displacement of the beam is small, and there is no separation between the shooter and the concrete.

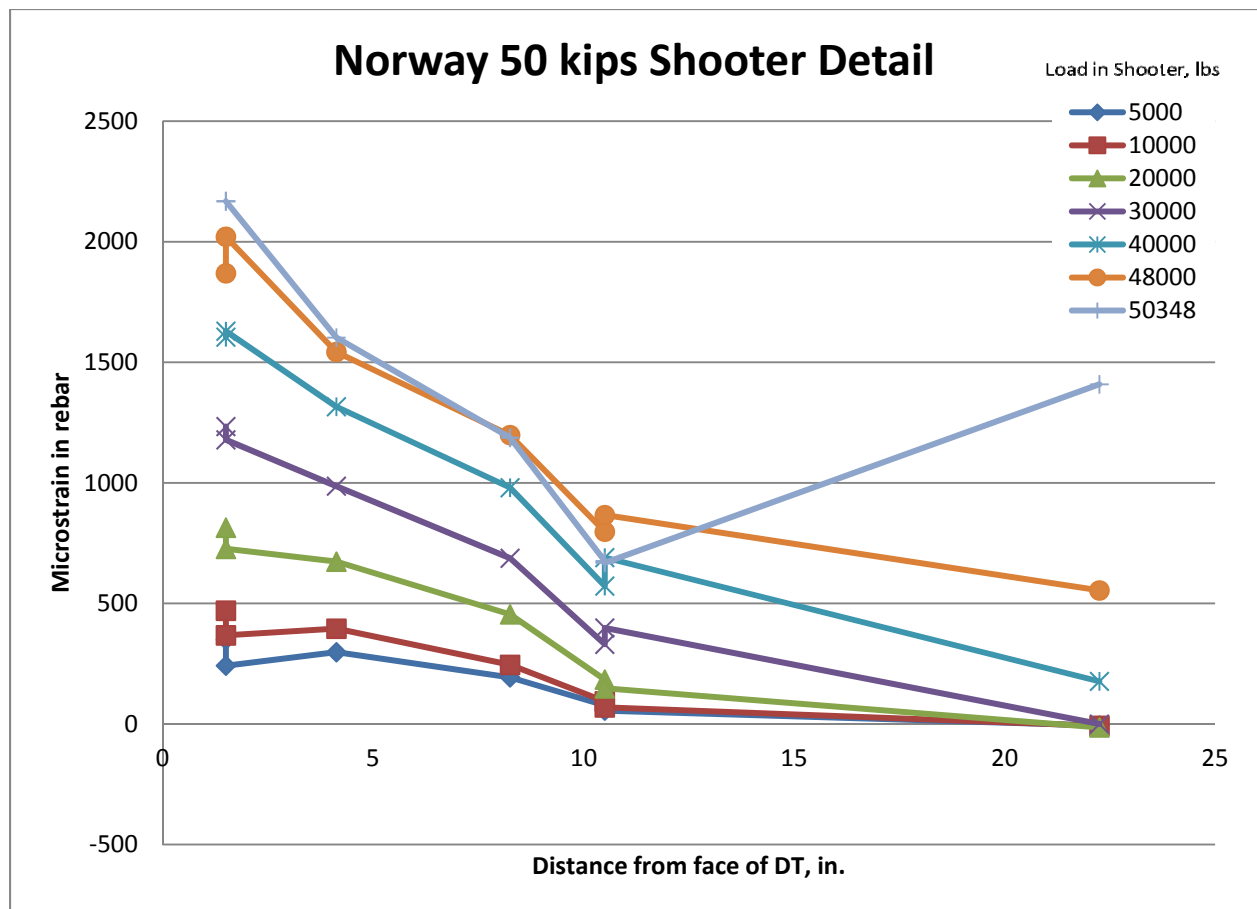


Figure 9: Microstrain in rebar vs. Distance from face of the double-tee for N50 Test

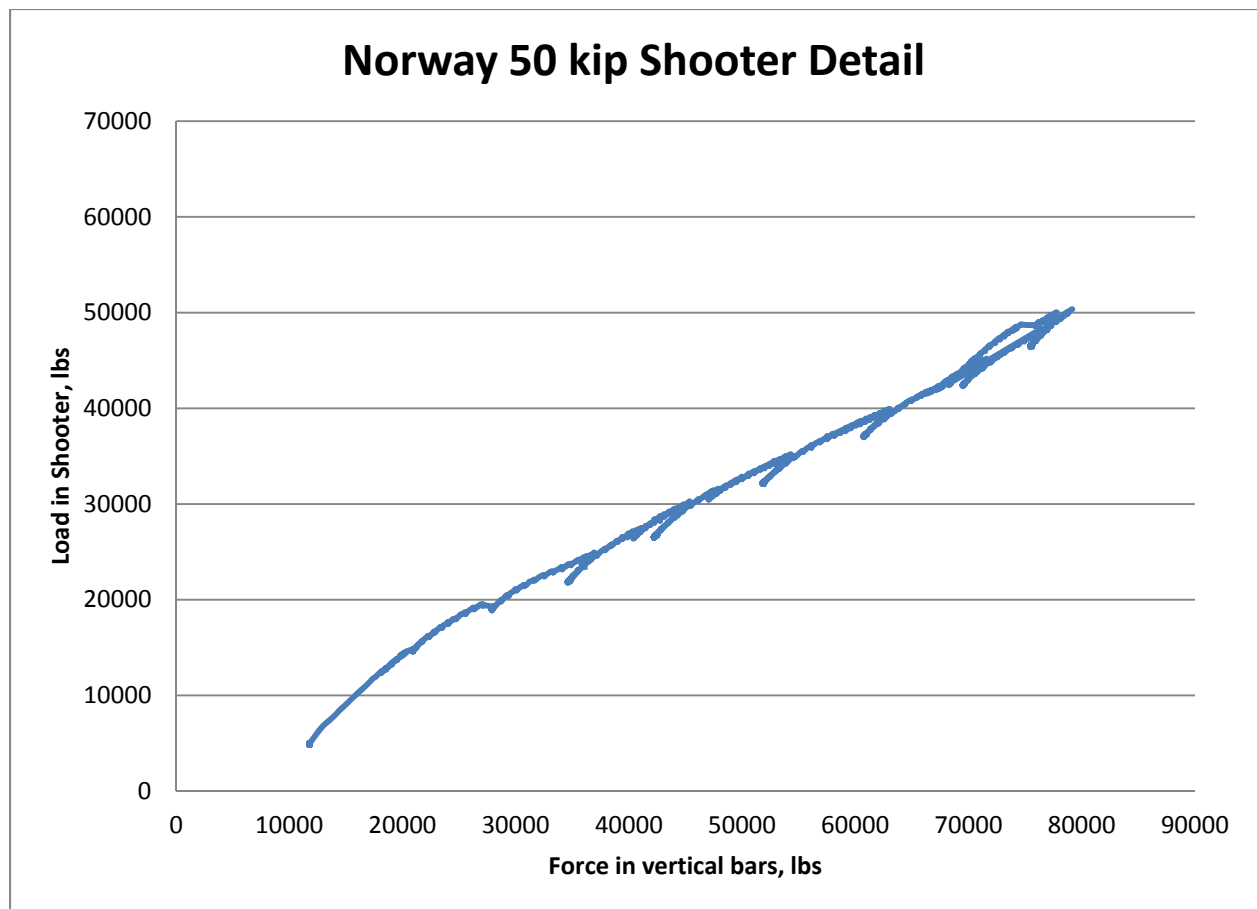


Figure 10: Load in the Shooter vs. Force in the vertical bars for N50 Test

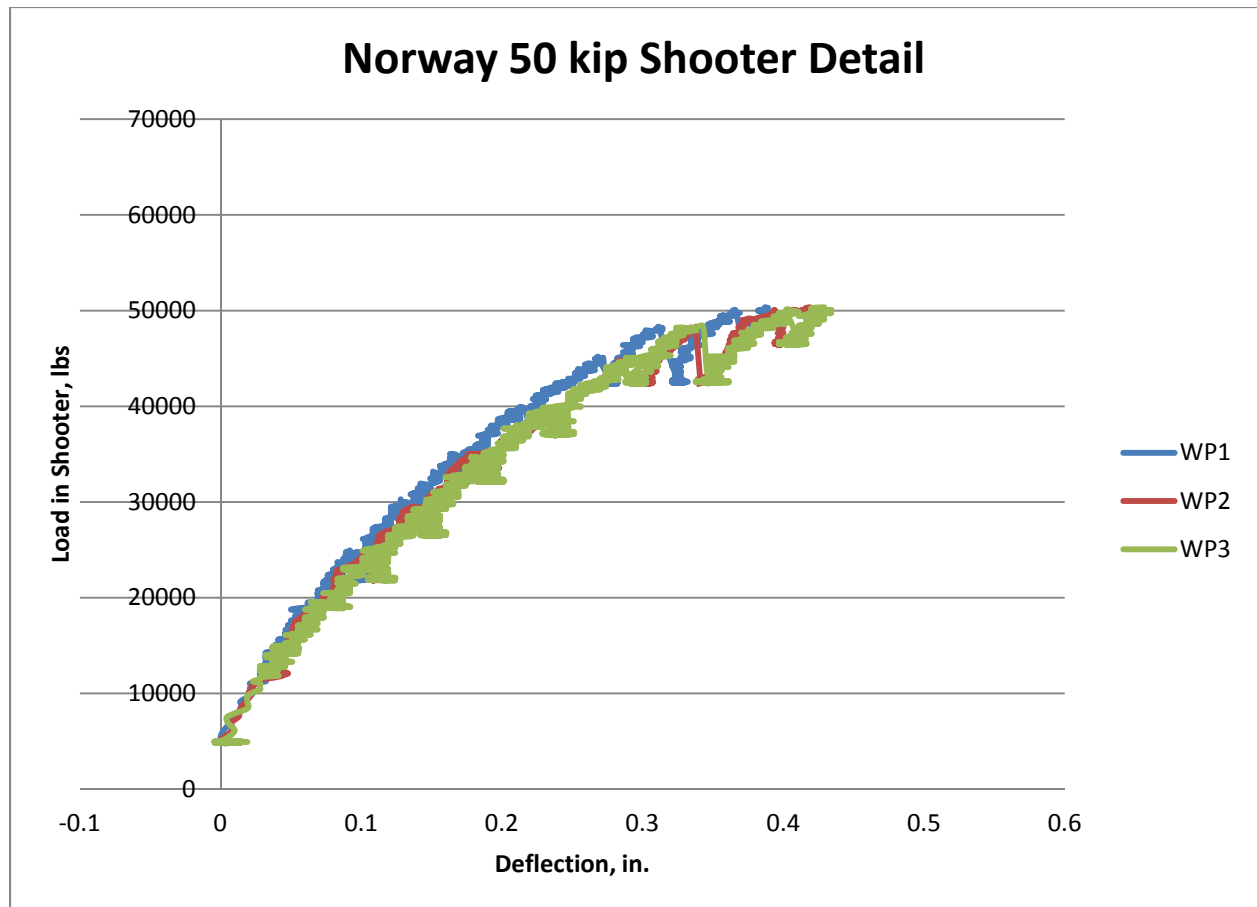


Figure 11: Load vs. Deflection for N50 Test

Jason 50 kip Shooter Test

The next test performed was on the Jason 50 kip Shooter. All instrumentation was zeroed while the shooter was not resting on the beam, as previously done. Loading proceeded until 10 kips was registered in the load cell under shooter, followed by additional increments of 5 kips until failure. After each increment of loading cracks were marked and then monitored to see how much, if any, they opened. This shooter failed at 51.4 kips. The warning crack at 48 kips occurred in this test as well, indicating that failure was near.

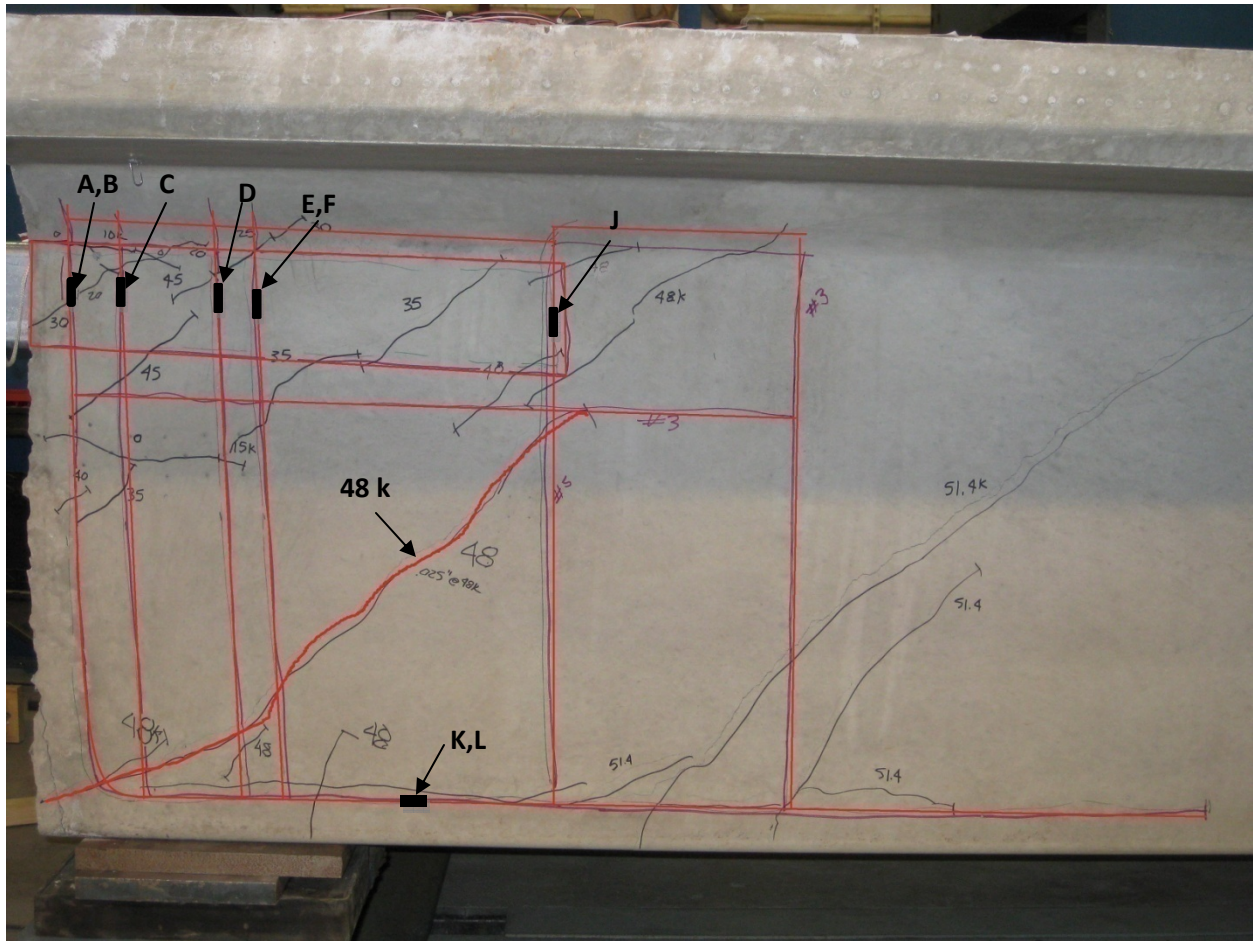


Figure 12: J50 Test

The gages that measured strain for this test are labeled with letters A thru L in Figure 12. Figure 13 shows the relationship between the load in the shooter and the strain in each gage. Once again the graph indicates that gages closer to the double-tee end experienced higher strains during testing and the bars farther from the face of the double-tee experience some tension at lower loads. The lower Victor bars, gages K and L, are not engaged until the concrete cracks across the bar the 48 kip warning load. The bar sizes and layout are presented in the shop drawings provided by Unistress located in Appendix A.



Figure 13: Load vs. Strain for all gages in J50 Test

The next graphs plot the strain in the rebar versus the distance from the face of the double-tee, the force in the front bars versus the load in the shooter, and the displacements of the three wire pots versus the load in the shooter. Figure 14 indicates that as the distance from the face of the double-tee increases, the strain in each gage decreases in a parabolic manner at each load step represented. Figure 15 indicates that the force resisted by the shooter is linearly related to the force in the first four bars of the cage. In previous calculations using a strut-and-tie model to determine the amount of reinforcing, it was estimated that the force in this region would be similar to the results obtained. Thus the reinforcing provided is sufficient to carry the load present in this region. In Figure 16 the displacements plotted for

the three different wire pots are similar and can be considered equivalent. This indicates that the displacement of the beam is small, and there is no separation between the shooter and the concrete.

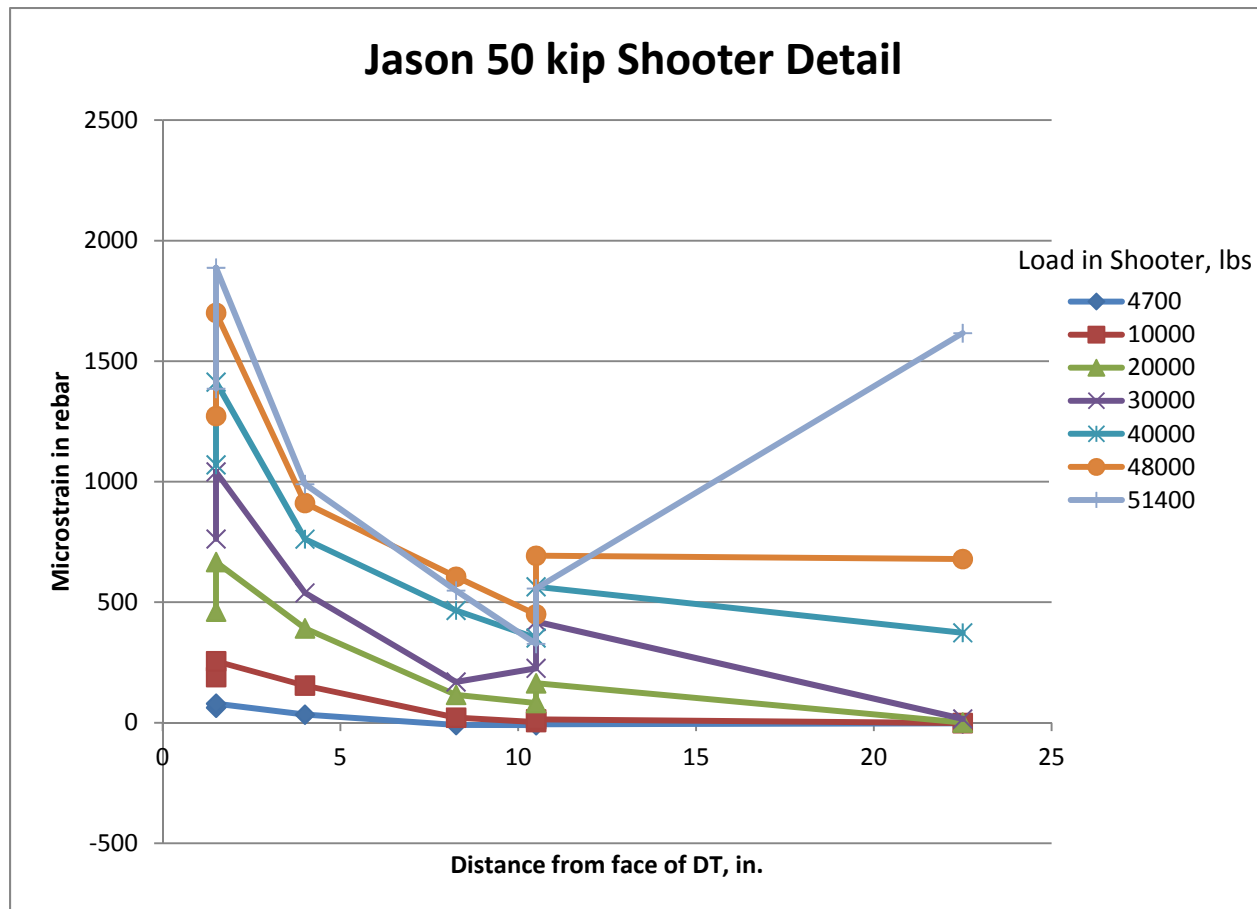


Figure 14: Microstrain in rebar vs. Distance from face of the double-tee for J50 Test

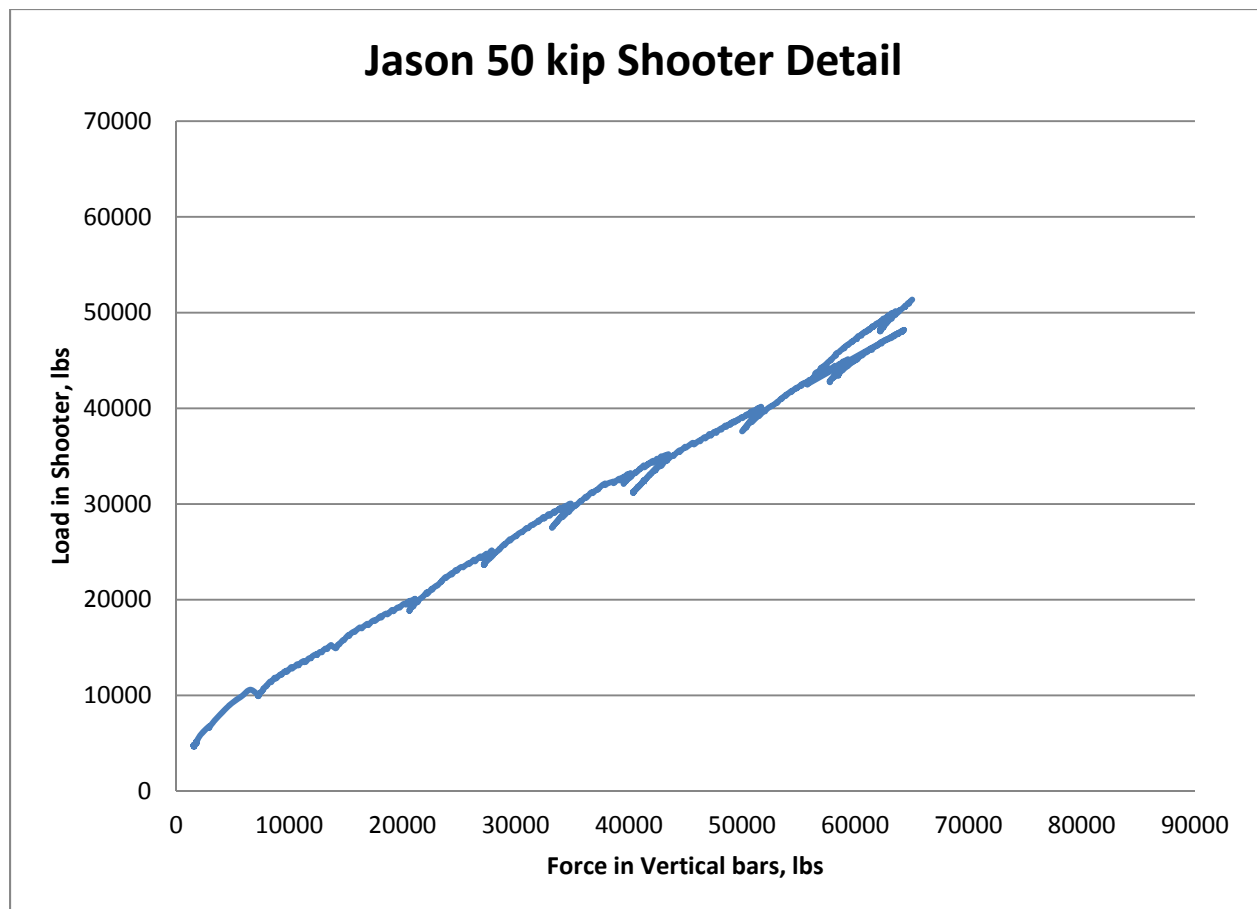


Figure 15: Load in the Shooter vs. Force in the vertical bars for J50 Test

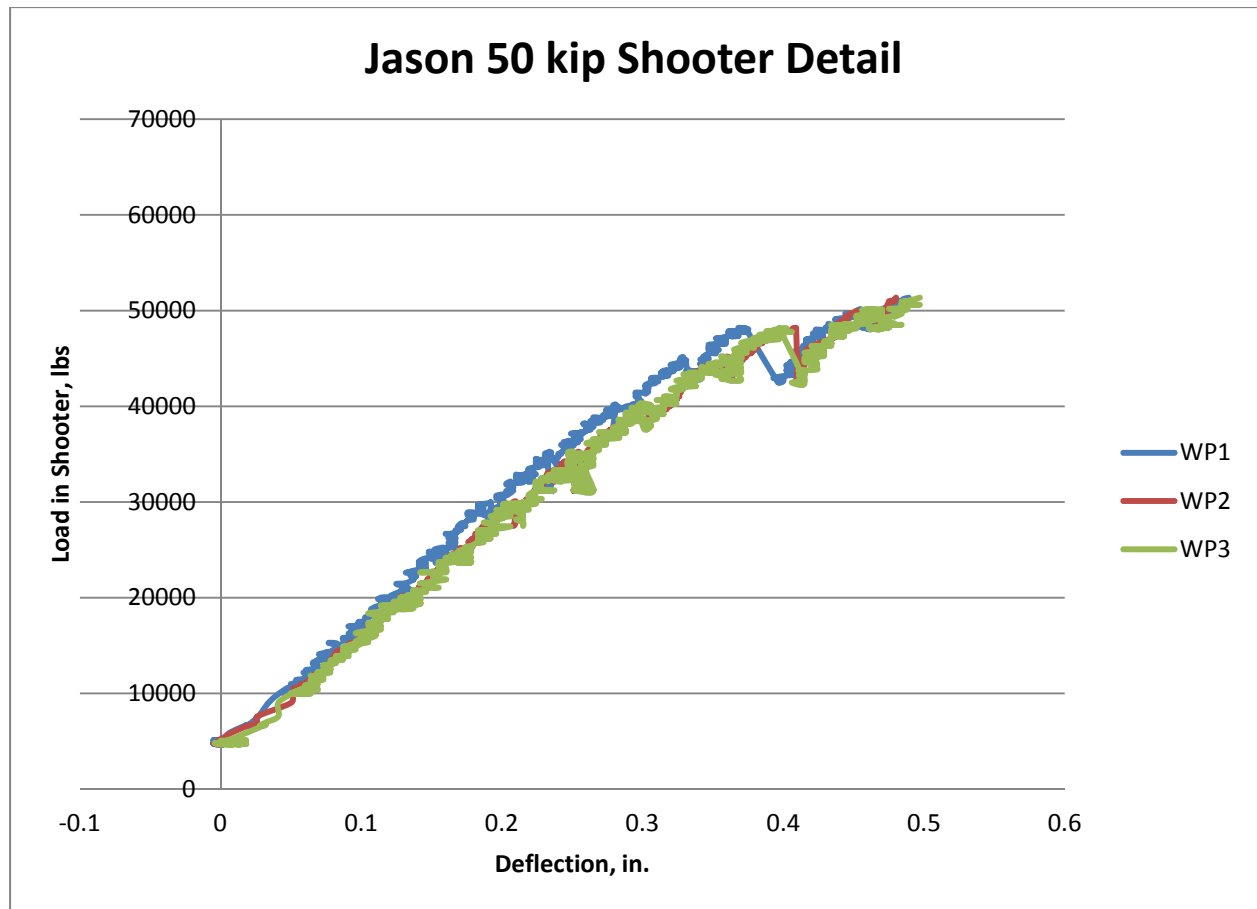


Figure 16: Load vs. Deflection for J50 Test

Norway 40 kip Shooter Test

The next test performed was on the Norway 40 kip Shooter. All instrumentation was once again zeroed while the shooter was not resting on the beam. Loading proceeded until 10 kips was registered in the load cell under the shooter, followed by additional increments of 5 kips until failure. After each increment of loading cracks were marked and then monitored to see how much, if any, they opened. This shooter failed at 55.3 kips, exceeding both the Norway 50 kip shooter and the Jason 50 kip shooter. Just as in the previous two tests, the warning crack at 48 kips occurred indicating that failure was near.

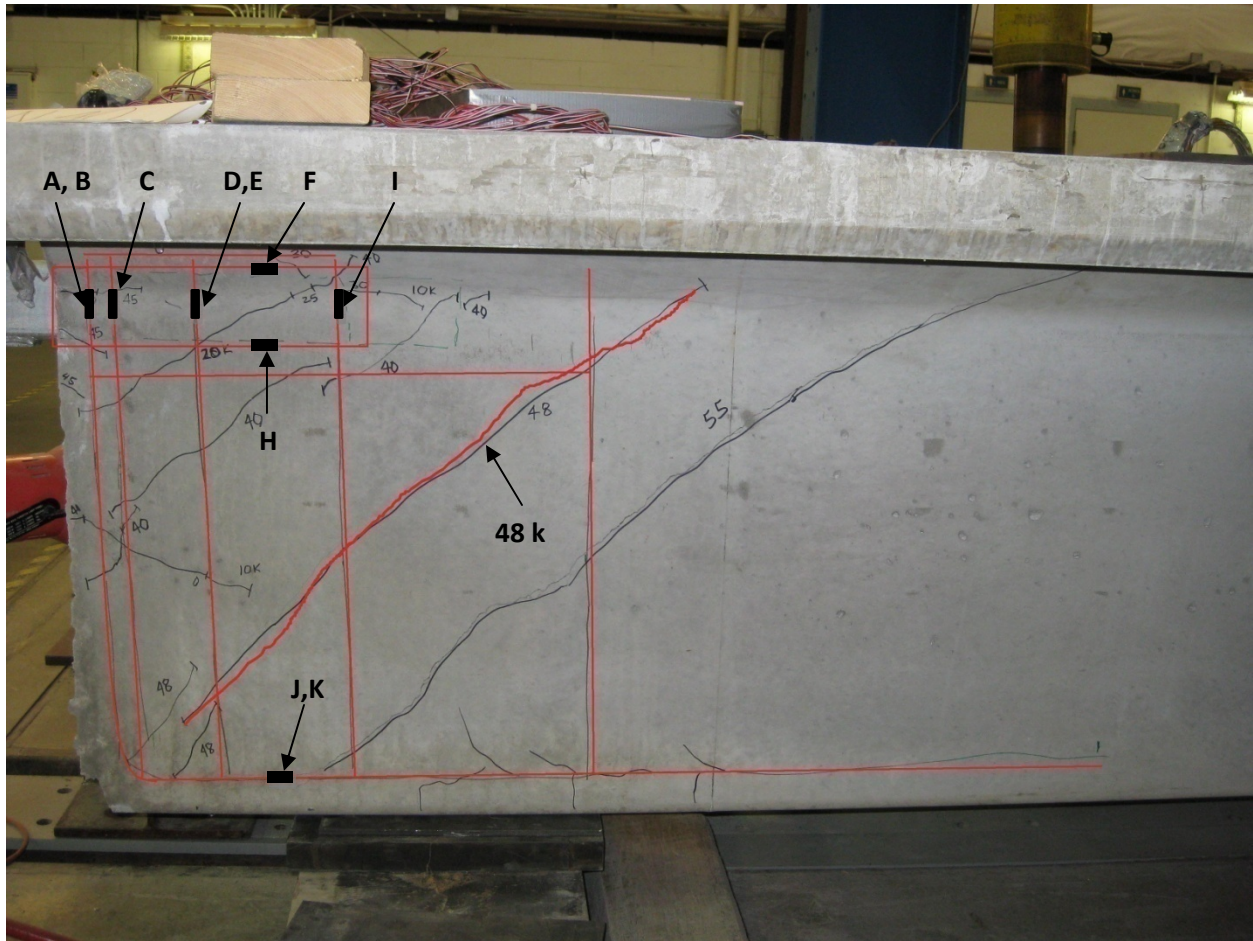


Figure 17: N40 Test

The gages that measured strain for this test are labeled with letters A thru K in Figure 17. Figure 18 shows the relationship between the load in the shooter and the strain in each gage on the rebar and the relationship between the load in the shooter and the strain on the shooter itself. Once again the graphs indicate that gages closer to the double-tee end experienced higher strains during testing and the bars farther from the face of the double-tee experience some tension at lower loads. The lower Victor bars, gages K and J, are not engaged until the concrete cracks across the bar the 48 kip warning load. The bar sizes and layout are presented in the shop drawings provided by Unistress located in Appendix A.

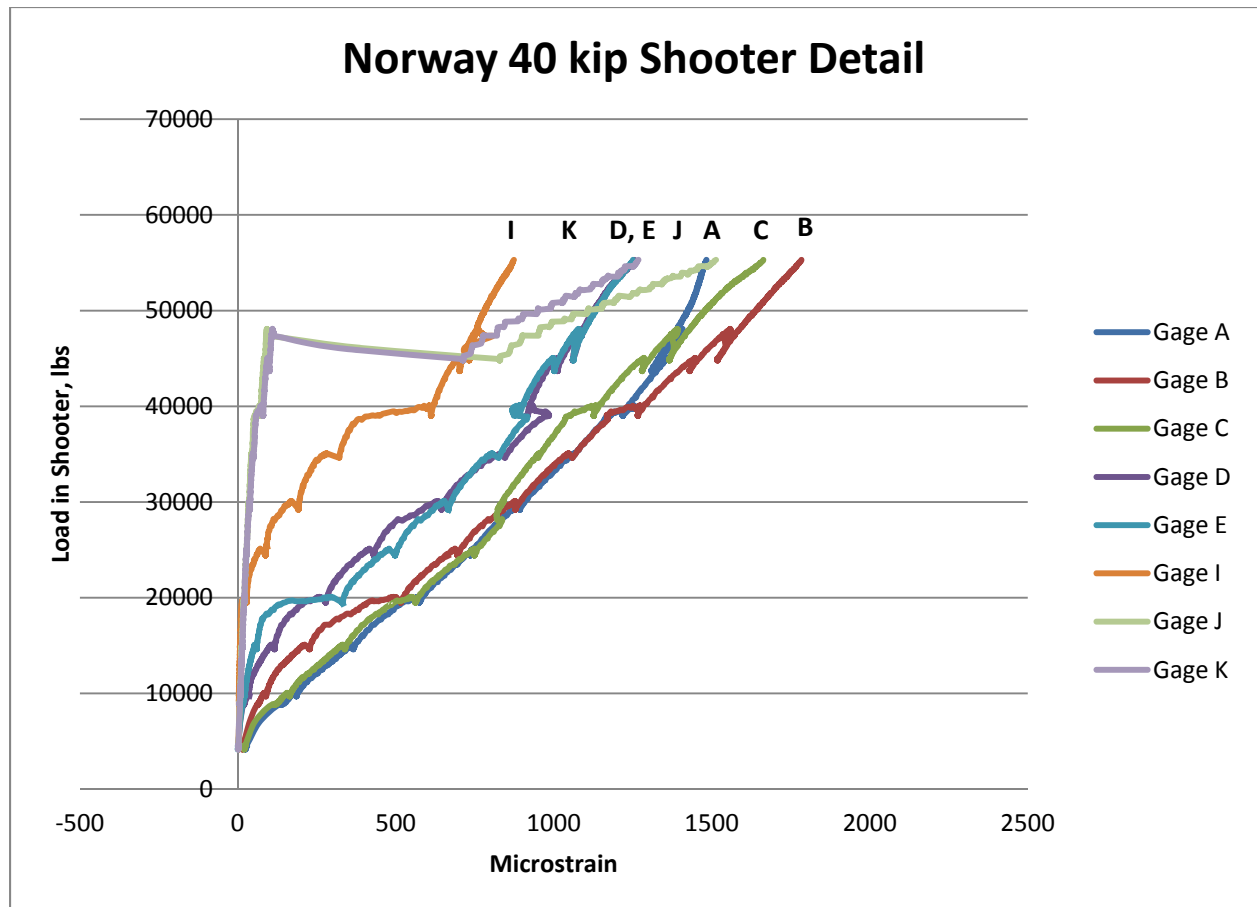


Figure 18: Load vs. Strain for gages on rebar in N40 Test

Figure 19 presents the strain measured by the gages adhered to the top and bottom of the outer tube of the shooter (gage H on bottom, gage F on top). As expected the bottom of the tube experiences tension. The strain in the top of the tube begins in compression, becomes tensile, and then returns to compression. Further analysis will be performed on the shooter itself. The other thing to note, however, is that the strains remain quite small at this location in the shooter (less than $600\mu\epsilon$).

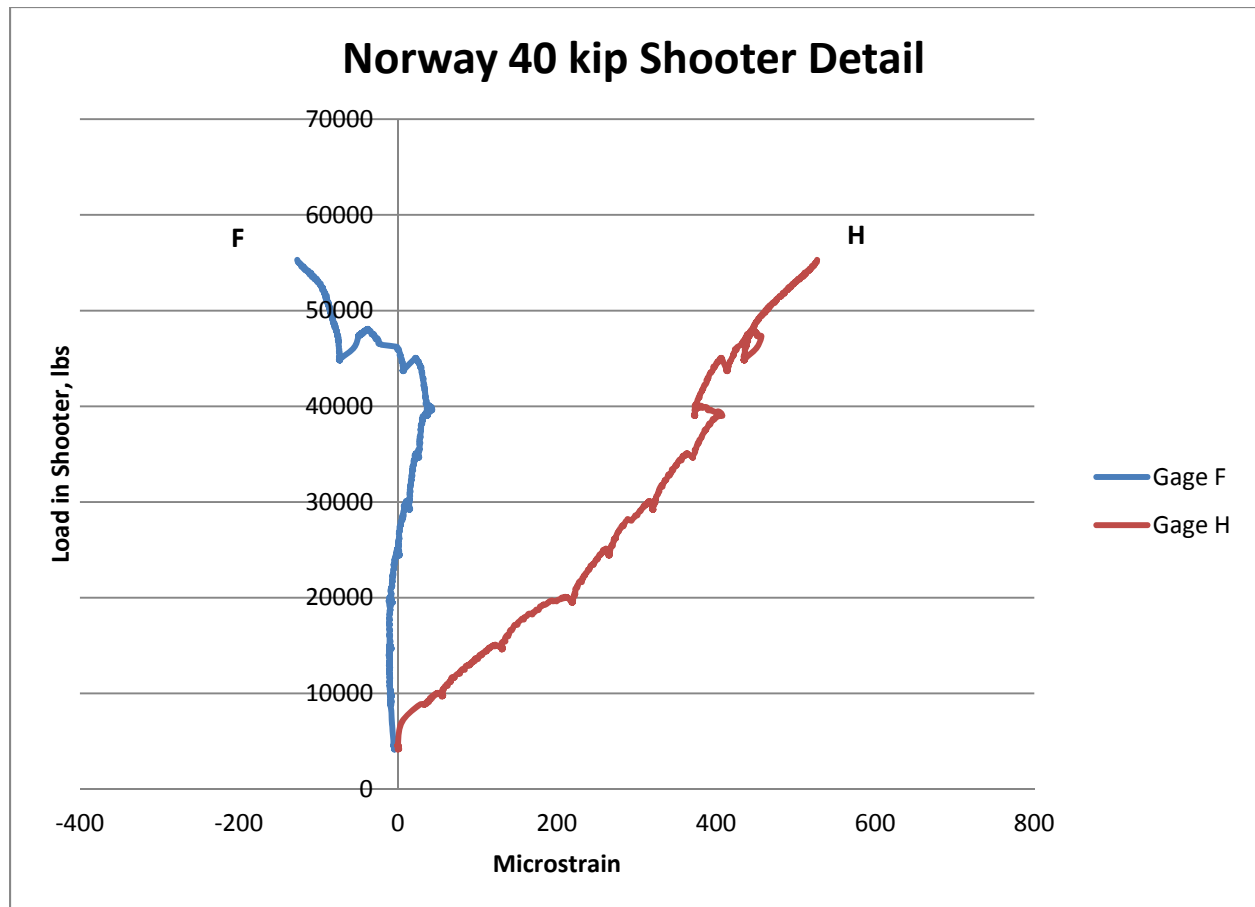


Figure 19: Load vs. Strain for gages on the Shooter in N40 Test

The next graphs plot the strain in the rebar versus the distance from the face of the double-tee, the force in the front bars versus the load in the shooter, and the displacements of the three wire pots versus the load in the shooter. Figure 20 indicates that as the distance from the face of the double-tee increases, the strain in each gage decreases in a linear manner at each load step represented. Figure 21 indicates that the force resisted by the shooter is linearly related to the force in the first four bars of the cage. In previous calculations using a strut-and-tie model to determine the amount of reinforcing, it was estimated that the force in this region would be similar to the results obtained. Thus the reinforcing provided is sufficient to carry the load present in this region. In Figure 22 the displacements plotted for

the three different wire pots are similar and can be considered equivalent. This indicates that the displacement of the beam is small, and there is no separation between the shooter and the concrete.

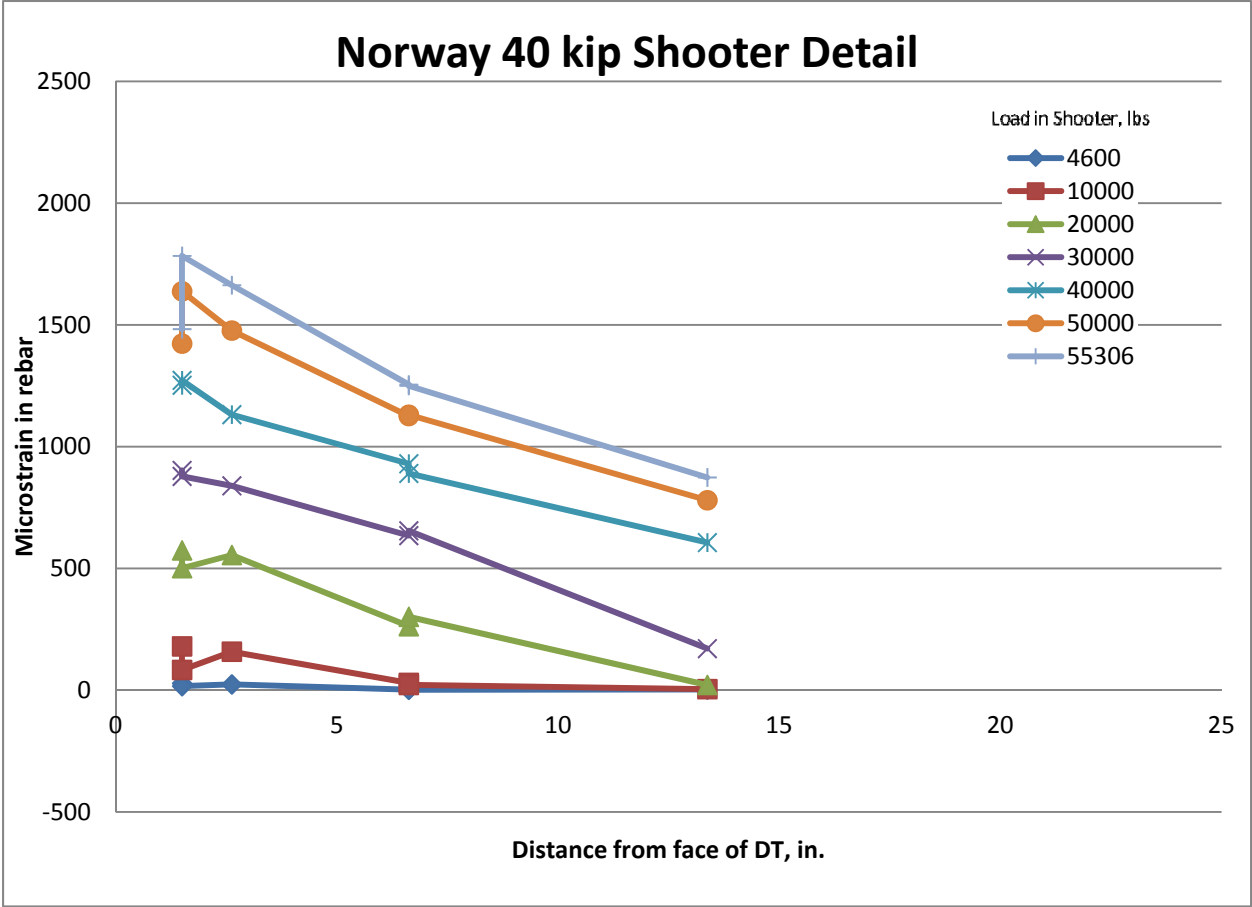


Figure 20: Microstrain in rebar vs. Distance from face of the double-tee for N40 Test

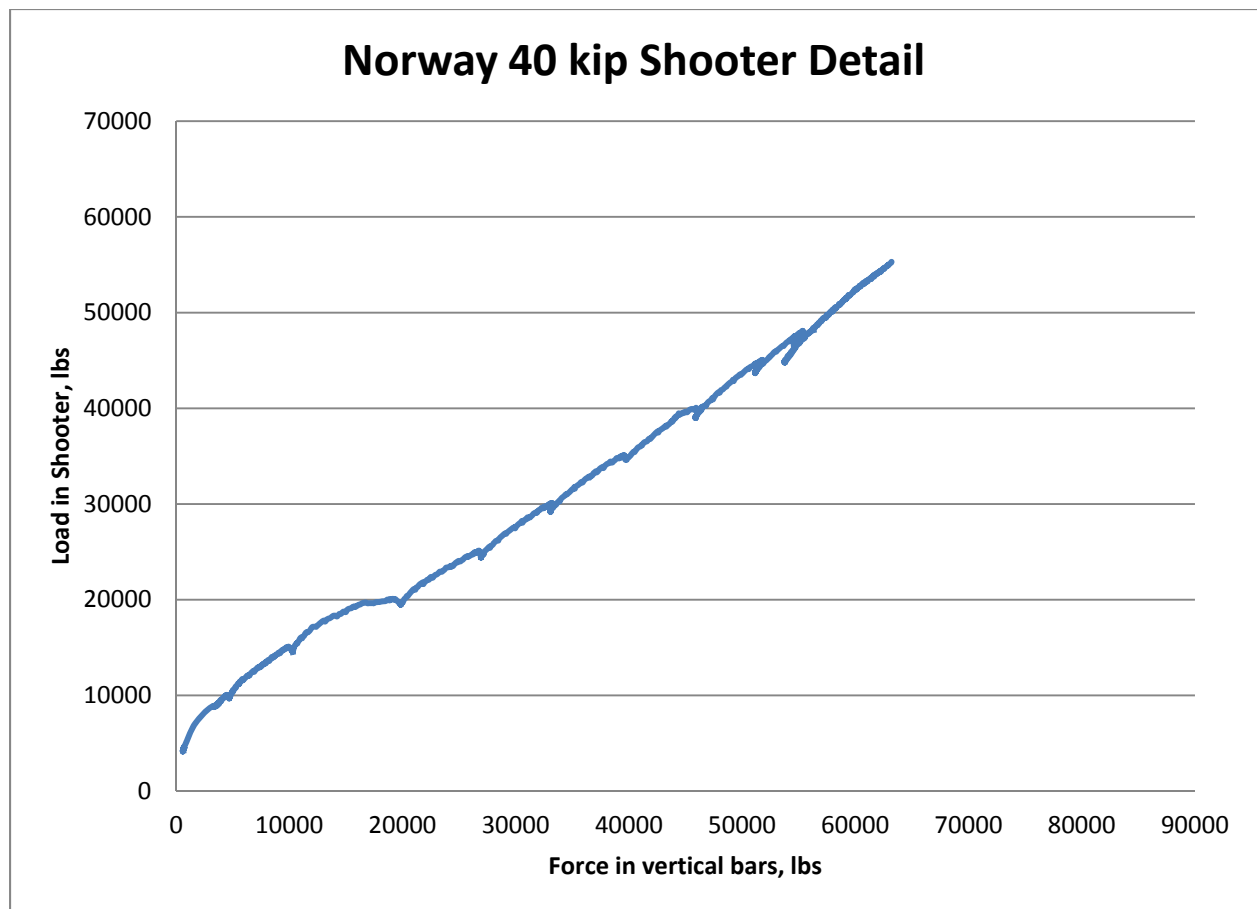


Figure 21: Load in the Shooter vs. Force in the vertical bars for N40 Test

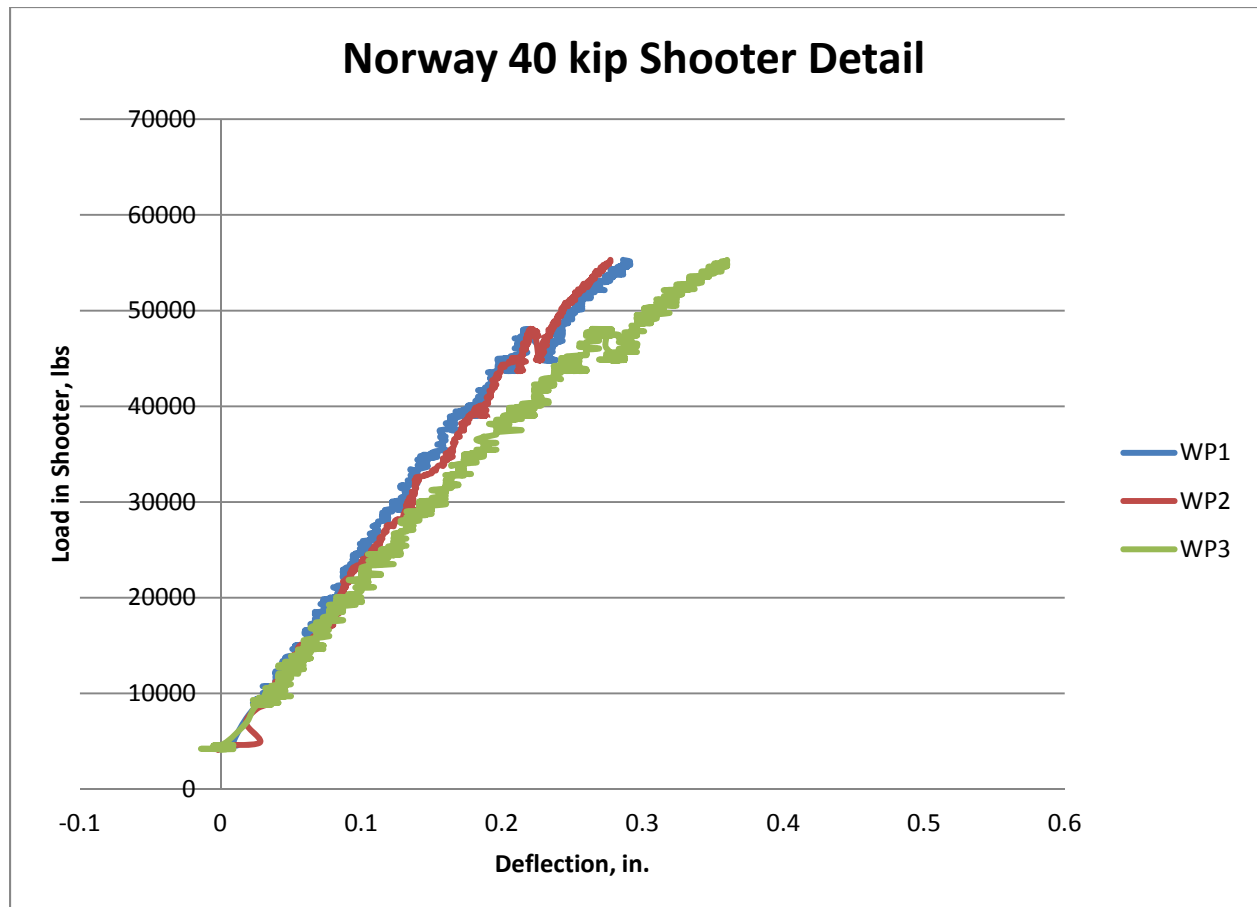


Figure 22: Load vs. Deflection for N40 Test

Jason 40 kip Shooter Test

The final test performed was on the Jason 40 kip Shooter. All instrumentation was zeroed the same way as the previous tests, while the shooter was not resting on the beam. Loading proceeded until 10 kips was registered in the load cell under the shooter, followed by additional increments of 5 kips until failure. After each increment of loading, cracks were marked and then monitored to see how much, if any, they opened. This shooter failed at 61.3 kips, exceeding the capacity of all the other shooters. Unlike the previous tests, cracks did not appear until higher loads and the warning crack at 48 kips did not occur. Failure for this test was much more sudden than the other tests.

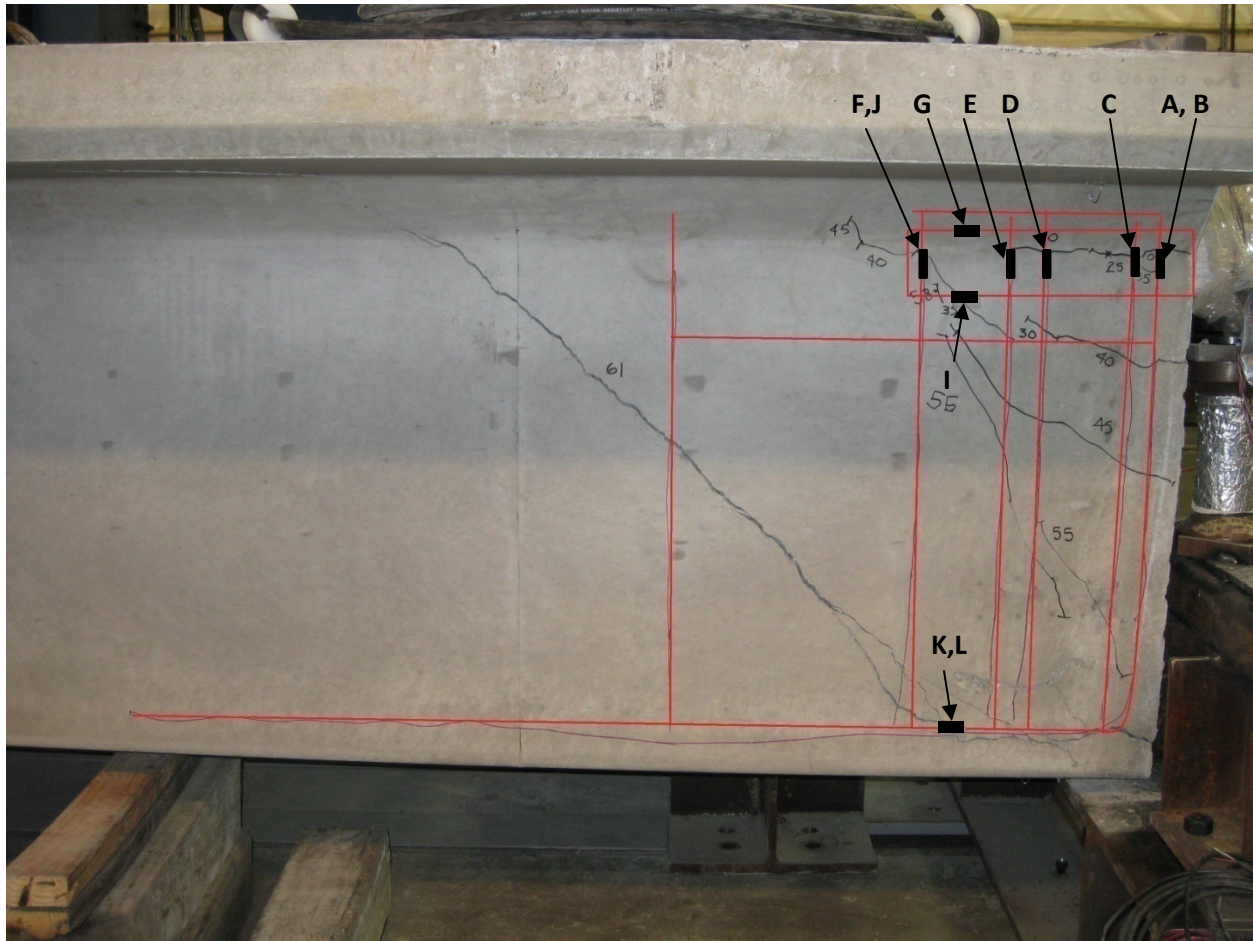


Figure 23: J40 Test

The gages that measured strain for this test are labeled with letters A thru L in Figure 23. Figure 24 shows the relationship between the load in the shooter and the strain in each gage on the rebar and the relationship between the load in the shooter and the strain on the shooter itself. Once again the graphs indicate that gages closer to the double-tee end experienced higher strains during testing and the bars farther from the face of the double-tee experience some tension at lower loads. The lower Victor bars, gages K and L, are not engaged until around 55 kips. However, the cracks formed at 55 kips were not sufficient to be a warning sign of failure. The bar sizes and layout are presented in the shop drawings provided by Unistress located in Appendix A.

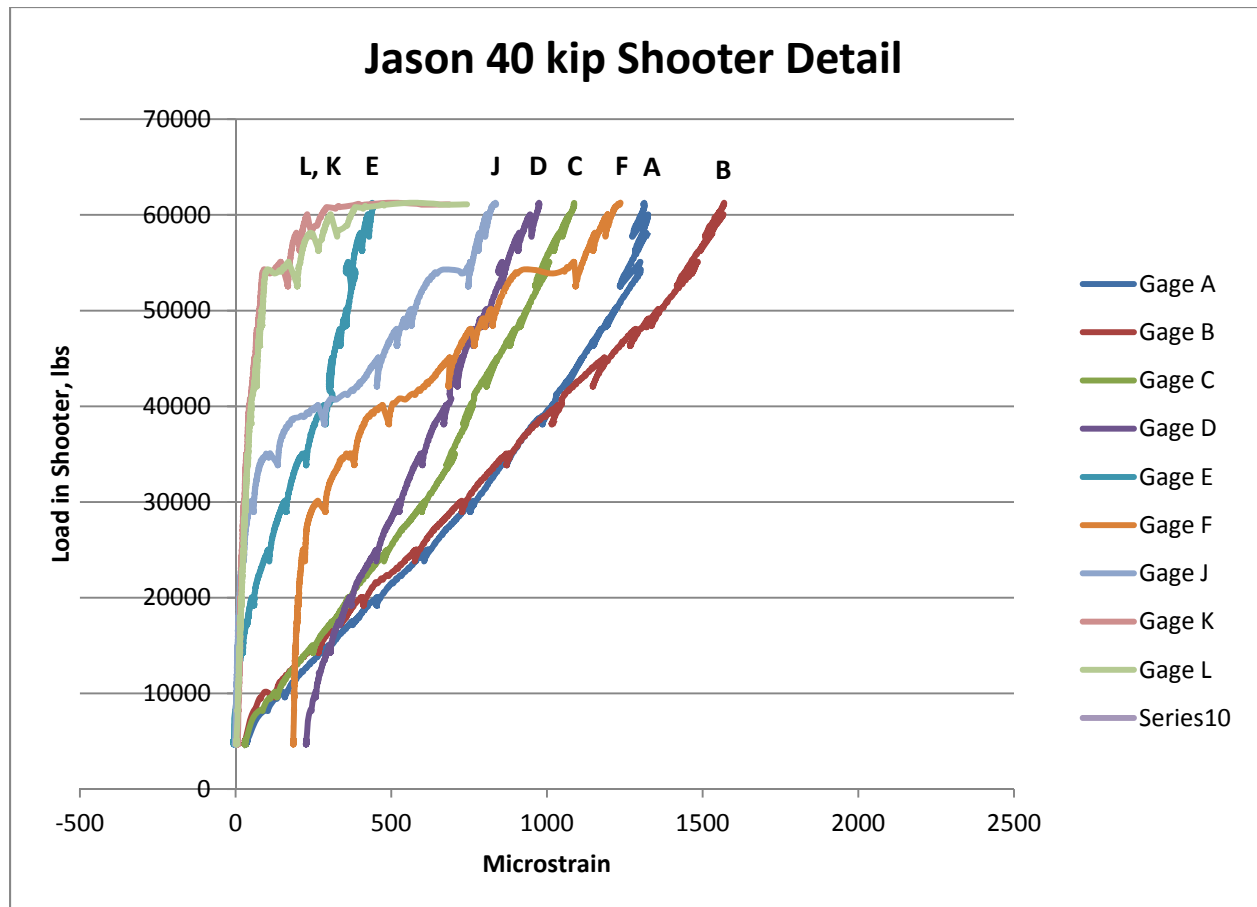


Figure 24: Load vs. Strain for gages on rebar in J40 Test

Figure 25 presents the strain measured by the gages adhered to the top and bottom of the outer tube of the shooter (gage I on bottom, gage G on top). As expected, the bottom of the tube experiences tension. Similar to what was seen in the Norway 40k tests, the strain in the top of the tube begins in compression, becomes tensile, and then returns to compression. Further analysis will be performed on the shooter itself. The strains at this location in the shooter also remain quite small (less than $700\mu\epsilon$).

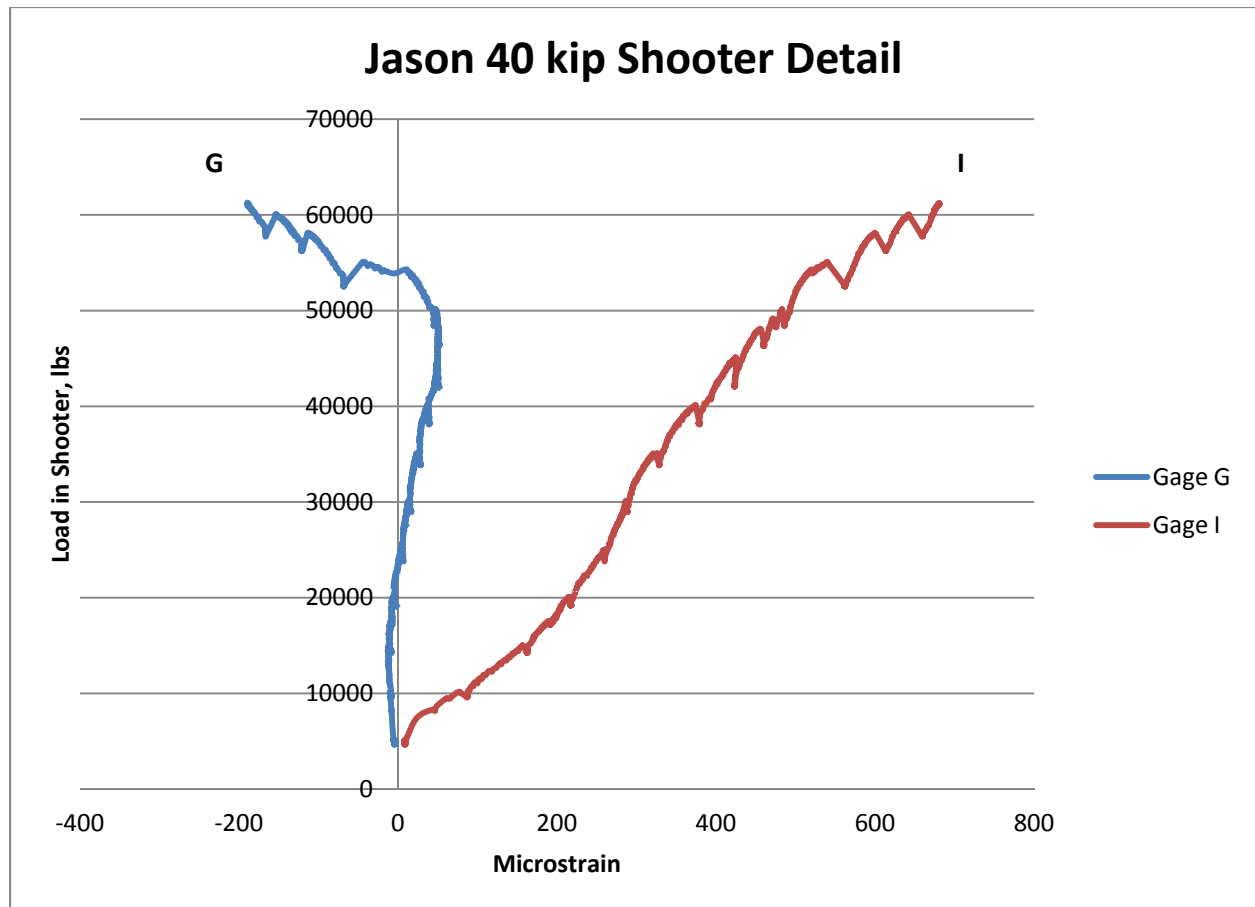


Figure 25: Load vs. Strain for gages on the Shooter in J40 Test

The next three graphs plot the strain in the rebar versus the distance from the face of the double-tee, the force in the front bars versus the load in the shooter, and the displacements of the three wire pots versus the load in the shooter. Figure 26 indicates that as the distance from the face of the double-tee increases, the strain in each gage decreases in a slightly parabolic manner at each load step represented. Figure 27 indicates that the force resisted by the shooter is linearly related to the force in the first four bars of the cage. In previous calculations using a strut-and-tie model to determine the amount of reinforcing, it was estimated that the force in this region would be similar to the results obtained. Thus the reinforcing provided is sufficient to carry the load present in this region. In Figure 28 the displacements plotted for the three different wire pots are similar and can be considered equivalent.

This indicates that the displacement of the beam is small, and there is no separation between the shooter and the concrete.

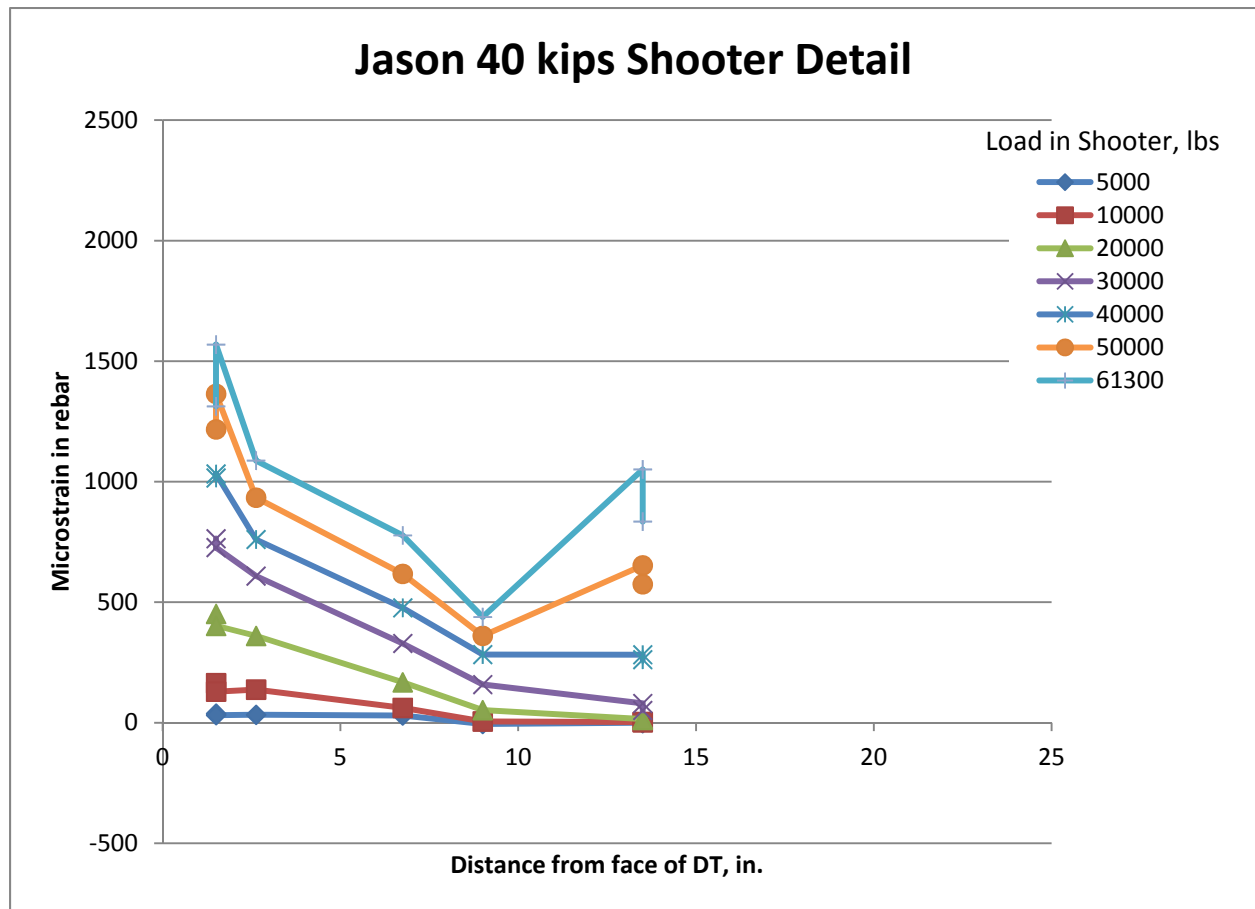


Figure 26: Microstrain in rebar vs. Distance from face of the double-tee for J40 Test

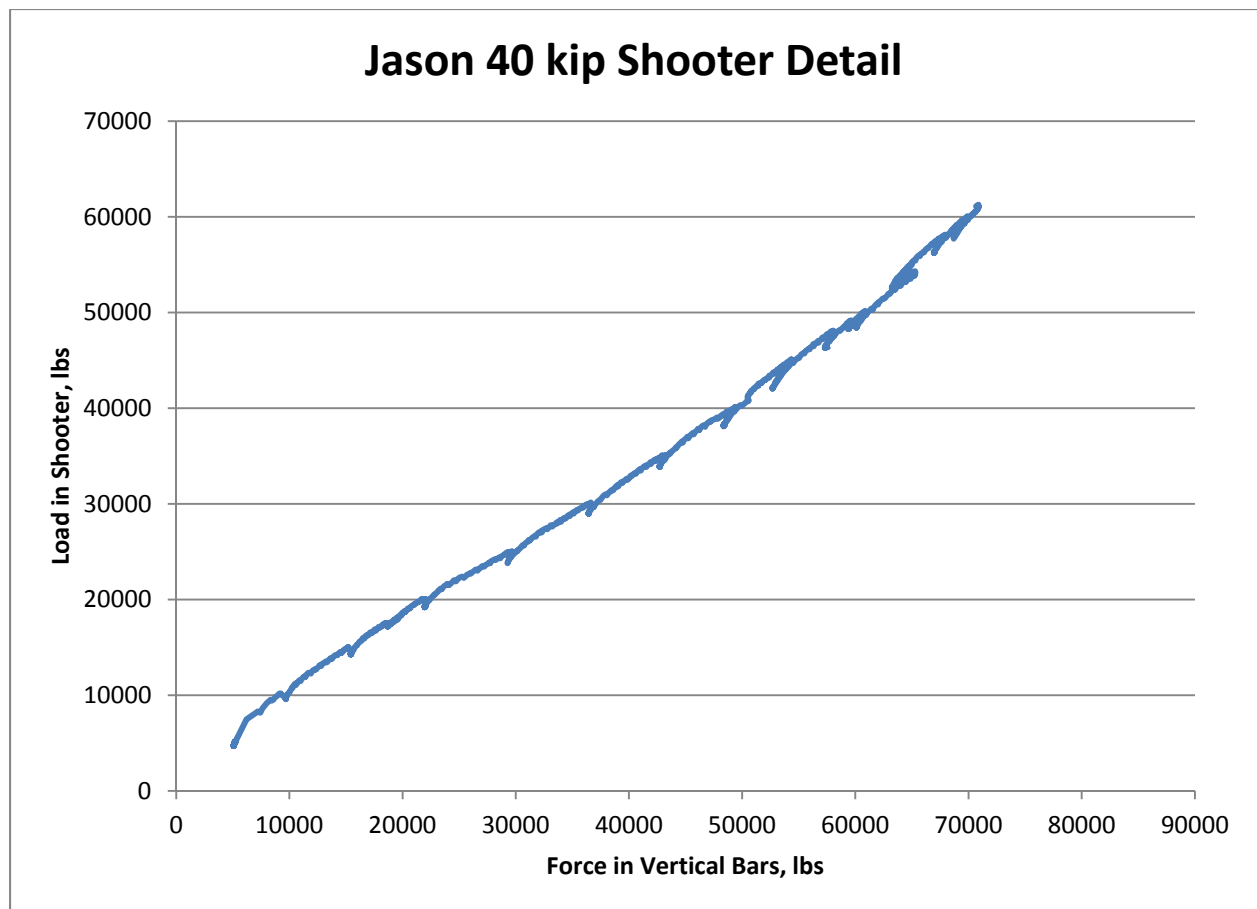


Figure 27: Load in the Shooter vs. Force in the vertical bars for J40 Test

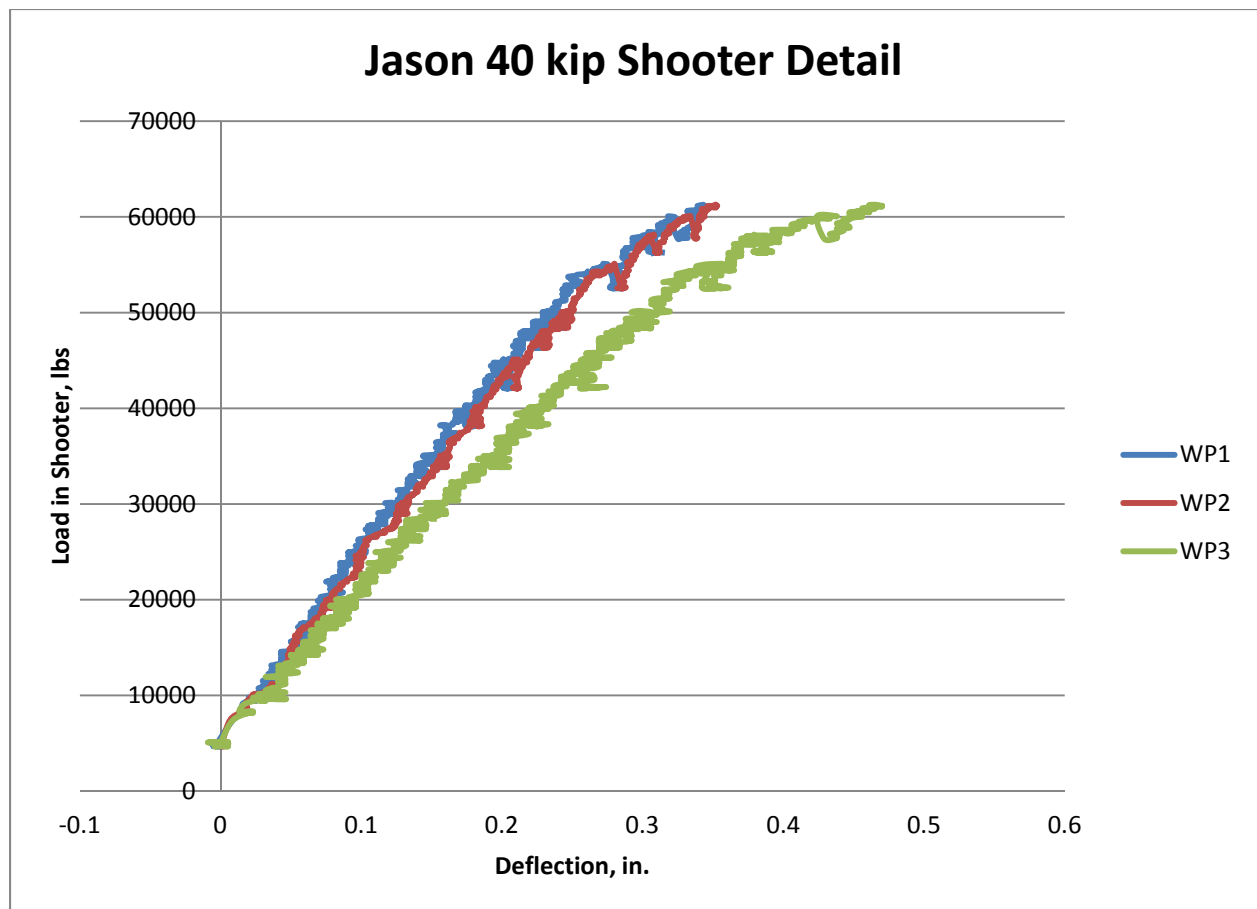
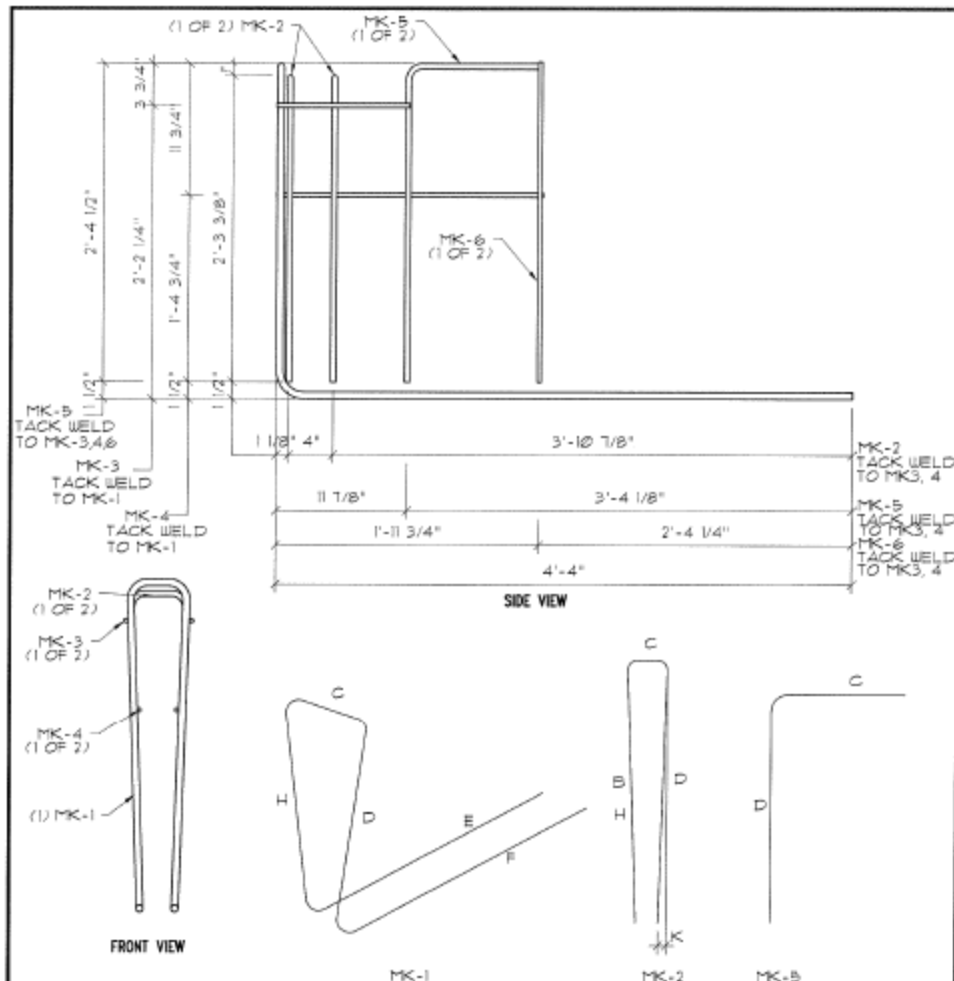
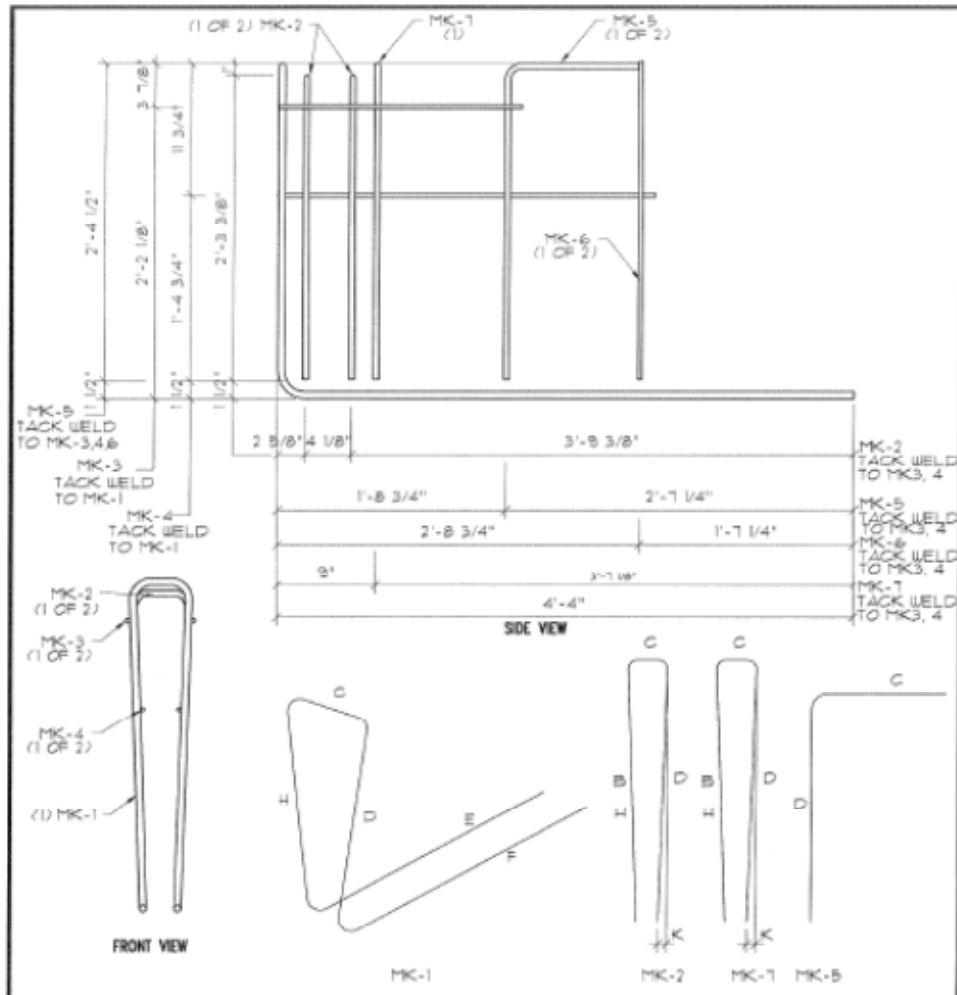


Figure 28: Load vs. Deflection for J40 Test

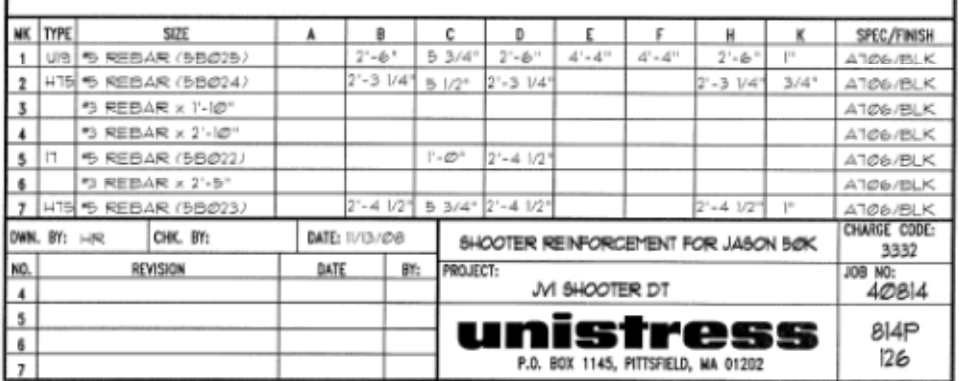
Appendix A

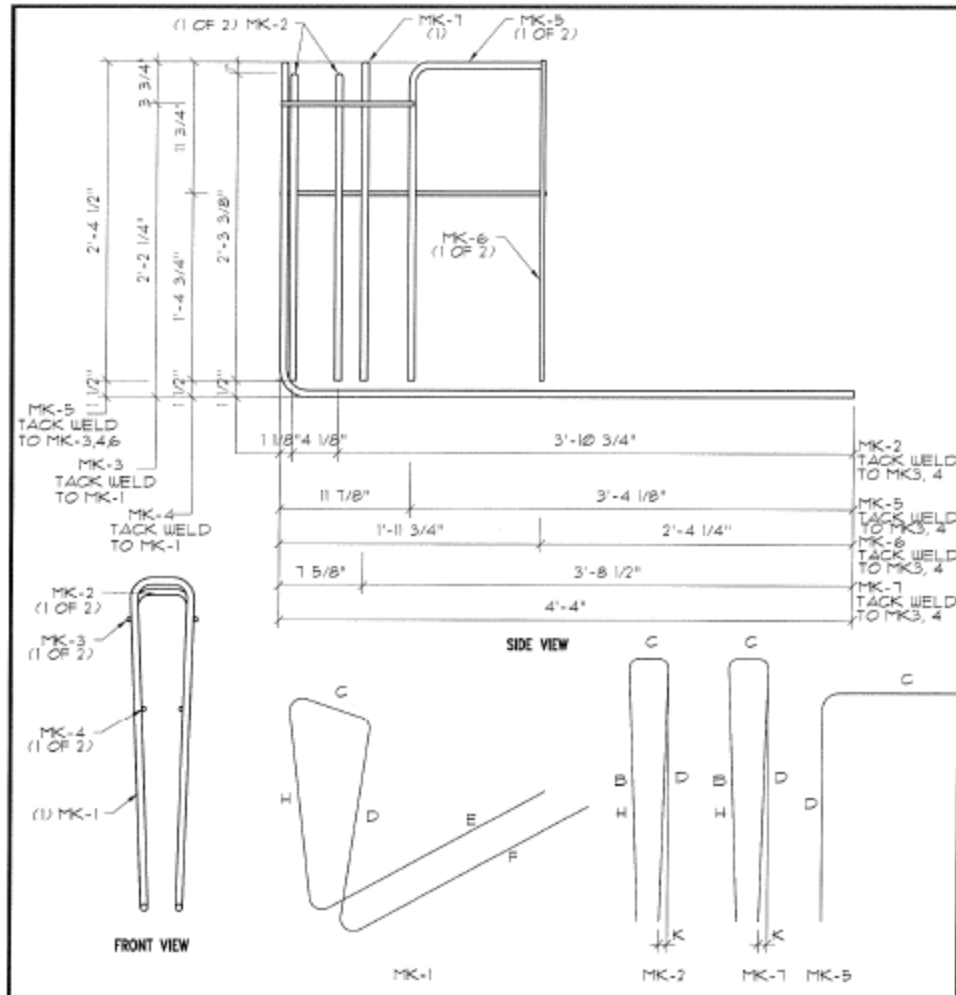


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1	UIS	#5 REBAR (5B025)		2'-6"	5 3/4"	2'-6"	4'-4"	4'-4"	2'-6"	1"	A706/BLK
2	HTB	#4 REBAR (4B081)		2'-3 1/4"	5 1/4"	2'-3 1/4"			2'-3 1/4"	3/4"	A706/BLK
3		#3 REBAR x 1'-0"									A706/BLK
4		#3 REBAR x 2'-0"									A706/BLK
5	IT	#4 REBAR (4B083)			1'-0"	2'-4 1/2"					A706/BLK
6		#3 REBAR x 2'-5"									A706/BLK
OWN. BY: HR			CHK. BY:		DATE: 11/13/08		SHOOTER REINFORCEMENT FOR NORWAY 40K				CHARGE CODE: 3332
NO.	REVISION		DATE		BY:		PROJECT: JVI SHOOTER DT				JOB NO: 40814
4							unistress P.O. BOX 1145, PITTSFIELD, MA 01202				814P 123
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WK	TYPE	SIZE	A	B	C	D	E	F	H	K	SPEC/FINISH		
1	U/S	#5 REBAR (5B0025)		2'-6"	5 3/4"	2'-6"	4'-4"	4'-4"	2'-6"	1"	A706/BLK		
2	H/S	#4 REBAR (4B0017)		2'-3 1/4"	5 1/4"	2'-3 1/4"			2'-3 1/4"	3/4"	A706/BLK		
3		#3 REBAR x 1'-10"									A706/BLK		
4		#3 REBAR x 2'-10"									A706/BLK		
5	I/I	#4 REBAR (4B0093)			1'-0"	2'-4 1/2"					A706/BLK		
6		#3 REBAR x 2'-5"									A706/BLK		
7	H/S	#4 REBAR (4B0088)		2'-4 1/2"	5 1/4"	2'-4 1/2"			2'-4 1/2"	1"	A706/BLK		
OWN. BY: HR			CHK. BY:		DATE: 11/13/08		SHOOTER REINFORCEMENT FOR NORWAY 50K					CHARGE CODE: 3332	
NO.		REVISION		DATE		BY:		PROJECT: JVI SHOOTER DT					JOB NO: 40814
4								JVI SHOOTER DT					
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MK	TYPE	SIZE	A	B	C	D	E	F	H	K	SPEC/FINISH
1	UB	#5 REBAR (5B025)		2'-6"	5 3/4"	2'-6"	4'-4"	4'-4"	2'-6"	1"	A706/BLK
2	HTB	#5 REBAR (5B024)		2'-3 1/4"	5 1/2"	2'-3 1/4"			2'-3 1/4"	3/4"	A706/BLK
3		#3 REBAR x 1'-0"									A706/BLK
4		#3 REBAR x 2'-0"									A706/BLK
5	IT	#5 REBAR (5B022)			1'-0"	2'-4 1/2"					A706/BLK
6		#3 REBAR x 2'-5"									A706/BLK
7	HTB	#5 REBAR (5B023)		2'-4 1/2"	5 3/4"	2'-4 1/2"			2'-4 1/2"	1"	A706/BLK
OWN. BY: HR			CHK. BY:		DATE: 11/13/08		SHOOTER REINFORCEMENT FOR JASON 40K				CHARGE CODE: 3332
NO.			REVISION		DATE		BY:		PROJECT: JVI SHOOTER DT		JOB NO: 40814
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