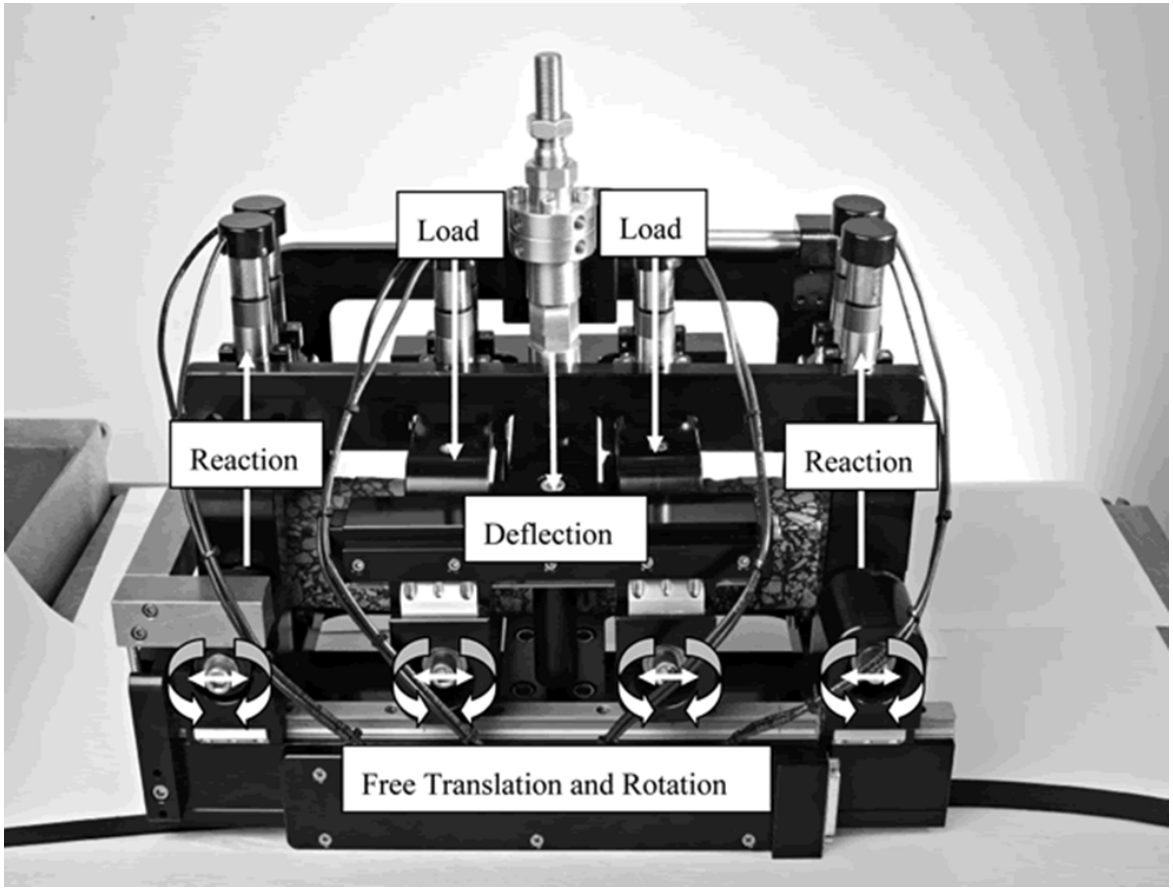
Difference Between Fixed and Floating Reference Points

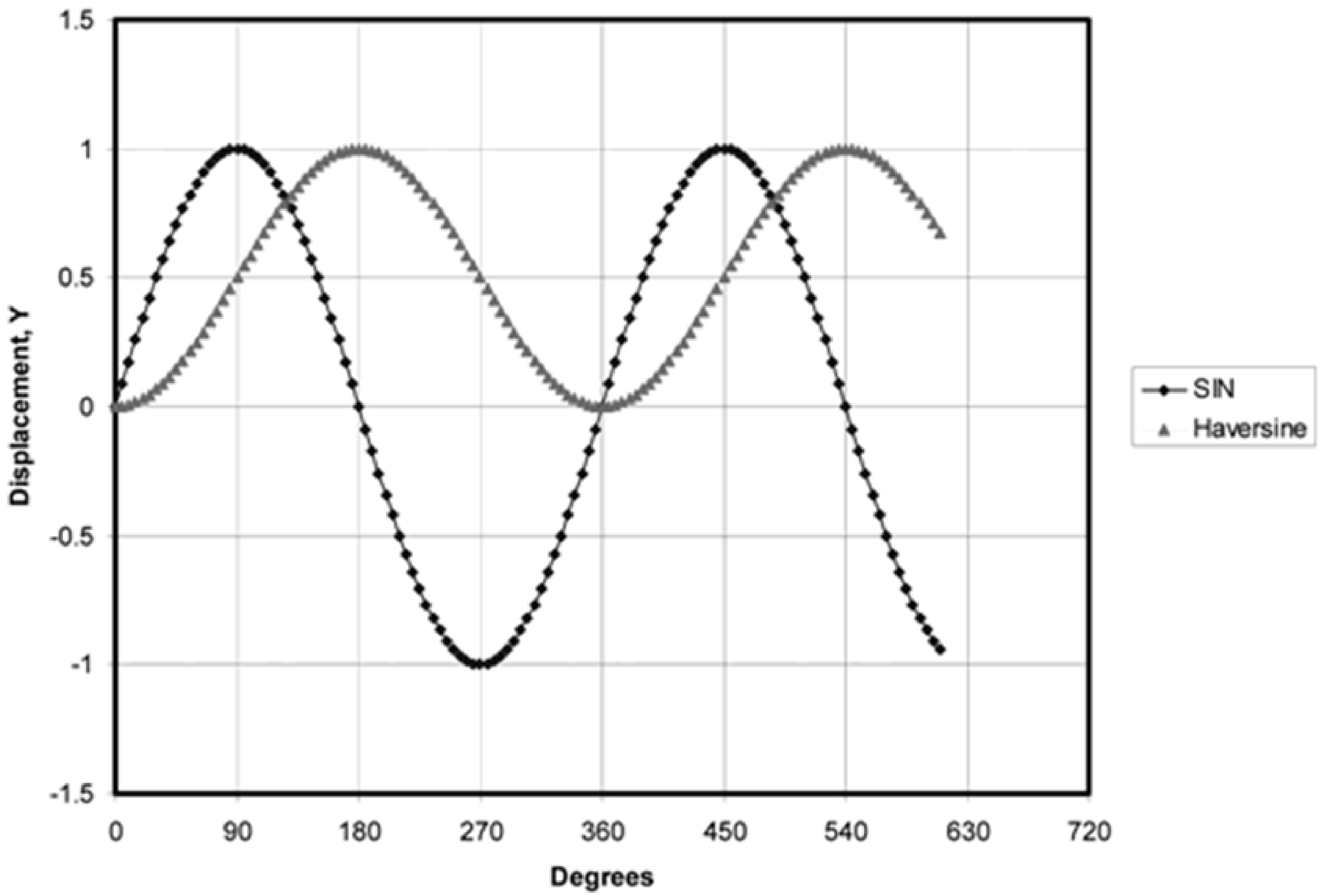
AASHTO

T-321

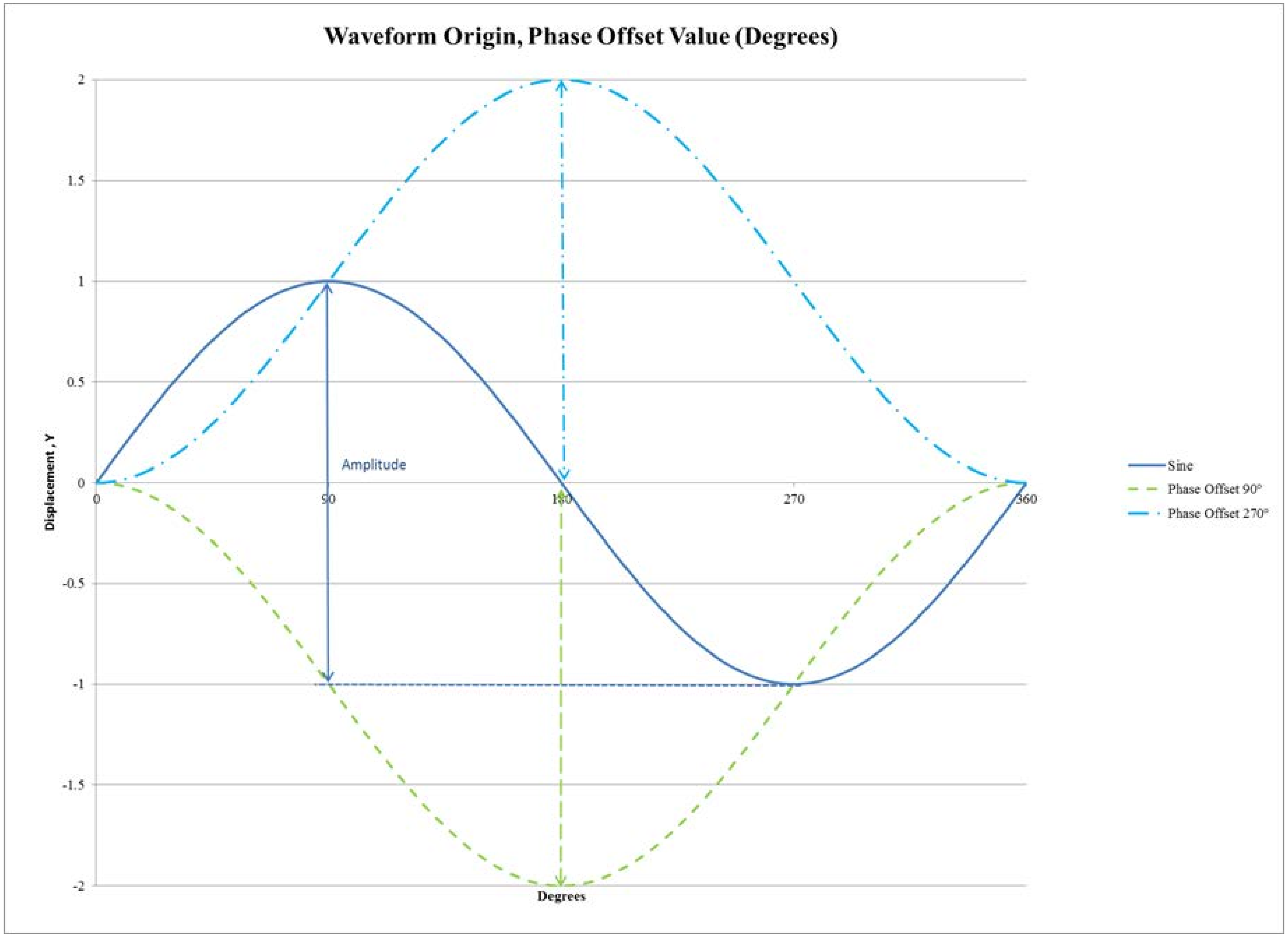
Fixed Reference LVDT with Target Attached to the Beam Neutral Axis (Mid-Height, Mid-Length)



Old ASTM D7460 Graph Improper Representation of Equipment Response



New ASTM D7460 Graph of Wave Response



Sinusoidal Waveforms @ 90° & 270° Phase Offsets
Comparison Fixed vs. Floating Reference Points

FRM-006
Beam Fatigue Testing Summary
10 Hz, 15 C

Beam	Air Voids (%)	Level of Micro Strain	Initial Beam Stiffness (MPa)	Target Amplitude Calculated (mm)	Actual Amplitude at 50th Cycle (mm)	Report Amplitude at 50th Cycle (mm)	Test Termination (cycles)	Normalized Modulus Failure Point (cycles)
(FRM-006D) UTM (Down)Fixed Ref-Point				L (357)	L (357)	L (357)		
1	5.1	2000	1928	1.0721	1.0721	N/A	980,000	646,160
2	4.6	2000	1928	1.0949	1.0949	N/A	1,300,000	848,920
3	4.7	2000	1804	1.0888	1.0888	N/A	1,900,000	421,720
4	3.6	2000	1851	1.0766	1.0766	N/A	560,000	348,320
5	3.2	2000	1866	1.0784	1.0784	N/A	1,100,000	757,640
6	3.5	2000	1295	1.0776	1.0776	N/A	640,000	456,680
Average	4.1		1779	1.0814	1.0814			
(FRM-006E) UTM (Up)-Fixed Ref-Point				L (357)	L (357)	L (357)		
1	2.9	2000	2004	1.0607	1.0607	N/A	920,000	646,880
2	3.1	2000	1942	1.075	1.075	N/A	1,600,000	882,560
3	3.1	2000	1940	1.0748	1.0748	N/A	920,000	738,120
4	3.6	2000	1933	1.0883	1.0883	N/A	560,000	347,240
5	3.5	2000	1886	1.0896	1.0896	N/A	1,500,000	926,640
6	3.3	2000	1915	1.0706	1.0706	N/A	800,000	429,880
Average	3.3		1937	1.0765	1.0765			
				δx►Target	δx=½δc	δc		
(FRM-006G) Floating Ref-Point (UP)				L/6 (237)	L/6 (237)	L (Calc)		
1	3.9	2000	1606	0.5357	0.5372	1.0743	2,521,550	1,634,300
2	3.2	2000	1220	0.5377	0.5356	1.0712	2,304,000	1,278,390
3	3.1	2000	1682	0.5344	0.5335	1.067	1,426,130	901,570
4	3.6	2000	1875	0.5357	0.5366	1.0731	2,134,080	633,380
5	3.4	2000	1916	0.5356	0.534	1.0681	1,749,220	1,220,860
6	3.4	2000	1841	0.538	0.5385	1.0769	1,849,460	1,107,750
Average	3.4		1690	0.5362	0.5359	1.0718		

(FRM-006D) UTM (Down)Fixed Ref-Point

Mean	Stand Dev	COV
570,550	158,993	28

Removed the high and low values

(FRM-006E) UTM (Up)-Fixed Ref-Point

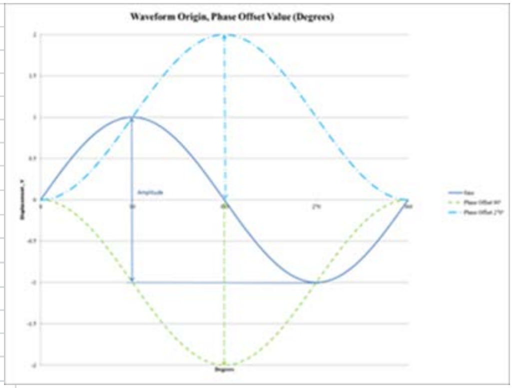
Mean	Stand Dev	COV
674,360	189,682	28

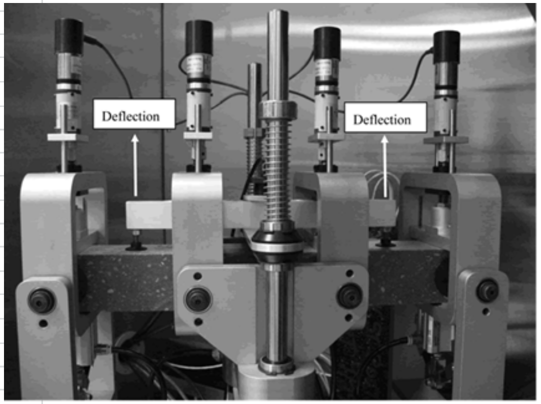
Removed the high and low values

(FRM-006G) Floating Ref-Point (UP)

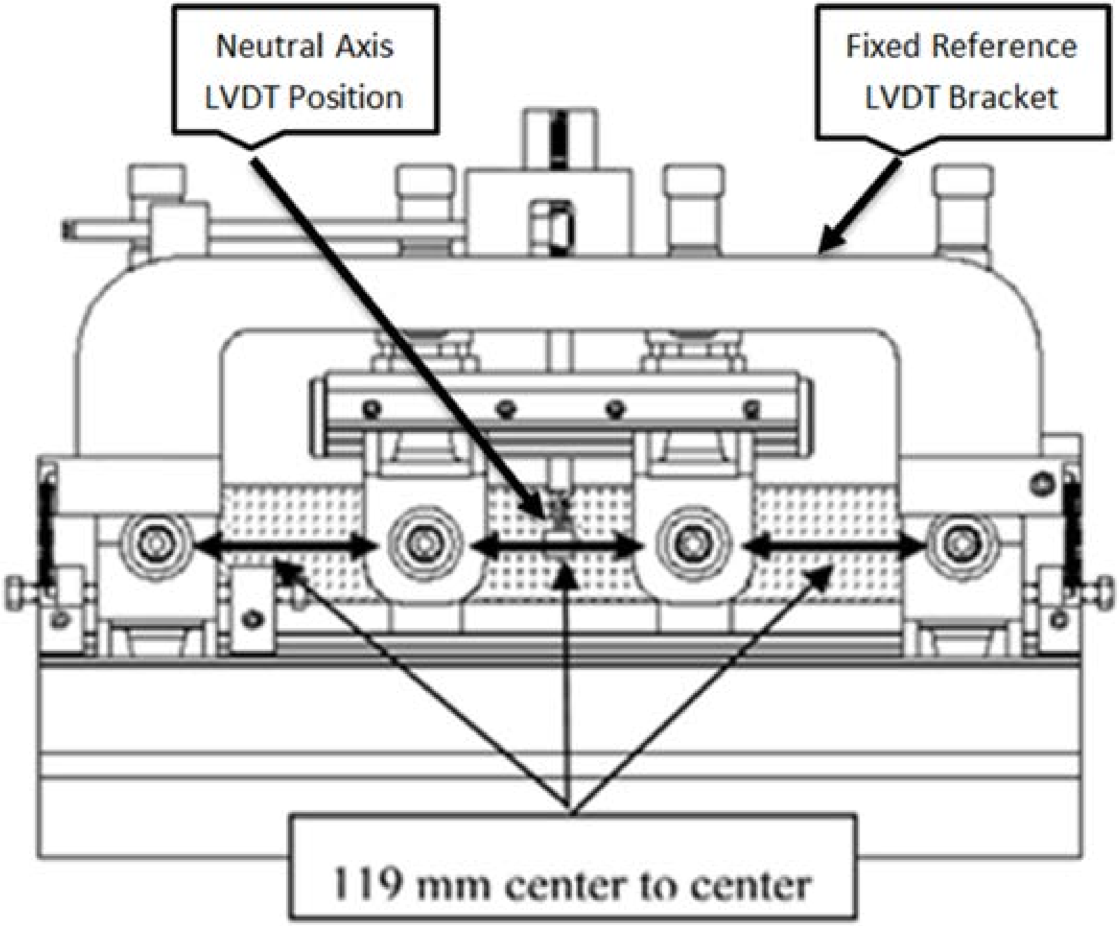
Mean	Stand Dev	COV
1,127,143	166,251	15

Removed the high and low values





Fixed Reference LVDT Flexural Beam Fatigue Test Apparatus, Side View



Fixed Reference LVDT

Fixed reference linear variable differential transducer (LVDT) closed loop controlling on a flexural beam fatigue (FBF) is defined as referencing the FBF frame that is bolted to the base plate. The LVDT is affixed to a free floating horizontal translation bar contacting three guide bearings on the outer fixed frames. Springs are used to stabilize the L-shaped bar from jumping the track and lifting off the bearings. The tension from the springs keep tension on the bar minimizing any variability in the LVDT readings as the test is being performed. The design makes no contact with the beam being tested other than the internal spring tension of the LVDT used to measure displacement.

- Reference point is fixed and never changing from cycle one throughout FBF test
- LVDT is referencing the target that is affixed to the neutral axis of the beam (½ the height & ½ the length of the beam)
- Equation in both ASHTO T-321 and ASTM D7460 reference the neutral axis for calculations

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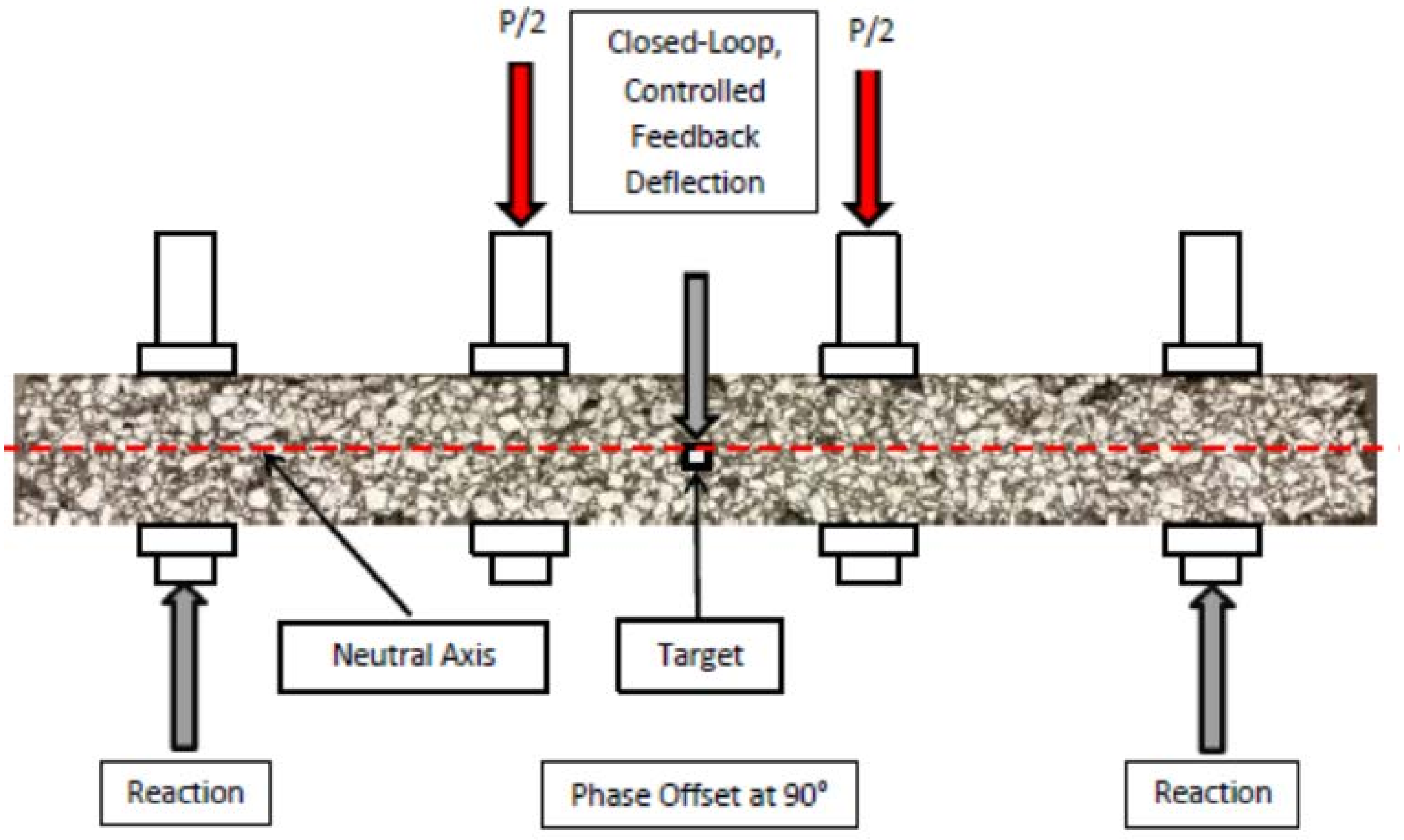
Load Characteristics of Fatigue Test Apparatus Illustrated at 90° Phase Offset



Load Characteristics of Fatigue Test Apparatus Illustrated at 270° Phase Offset

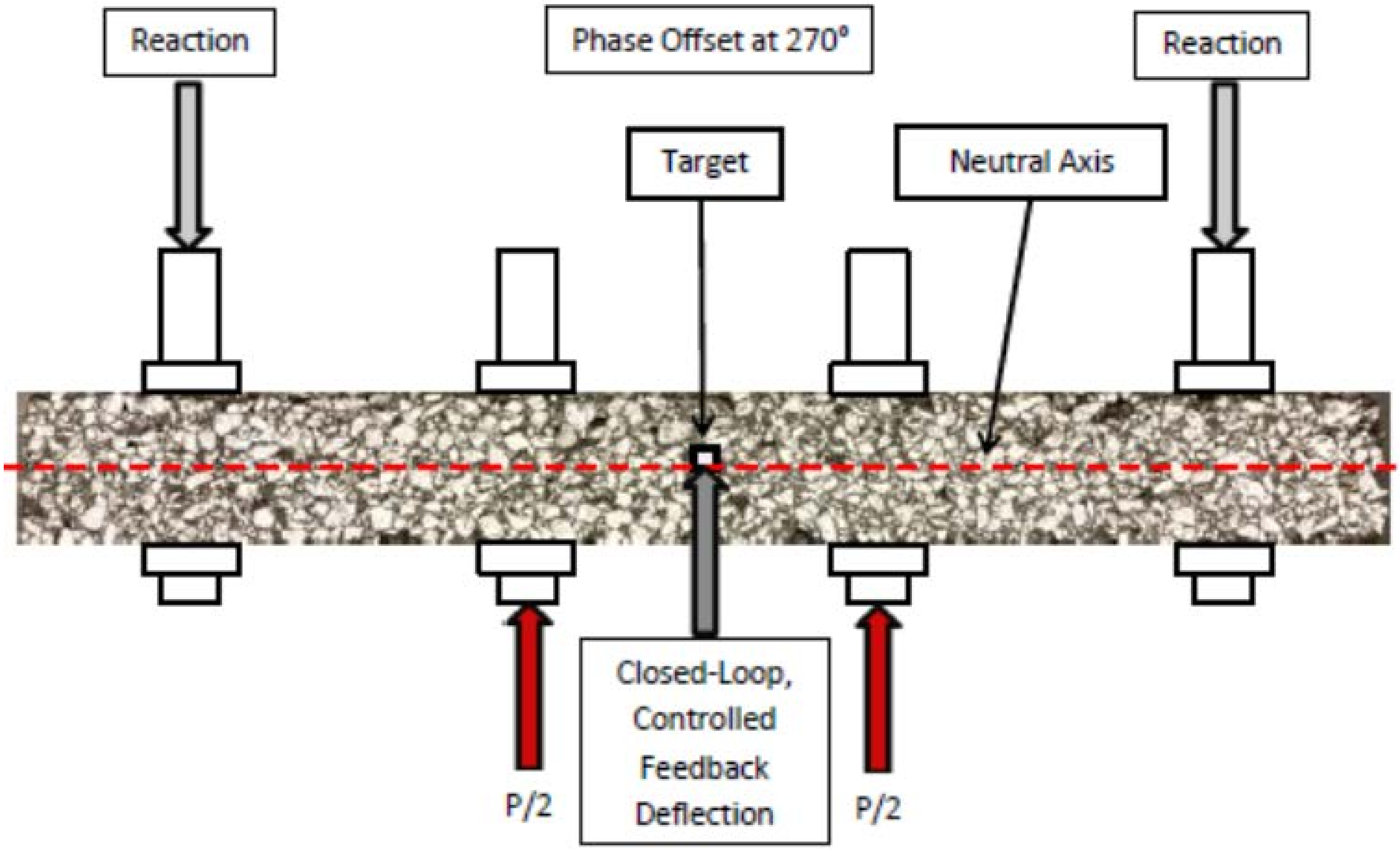
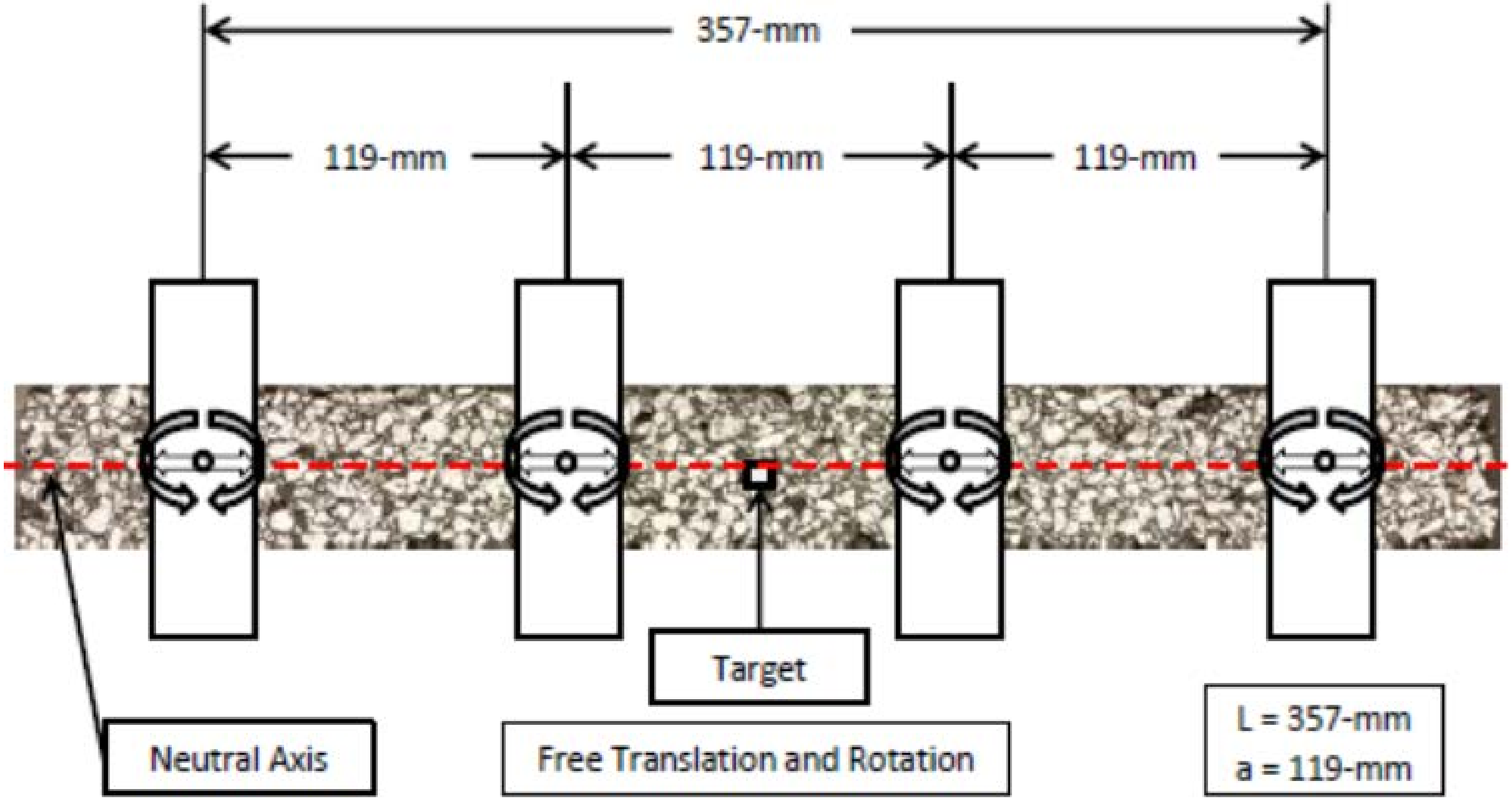
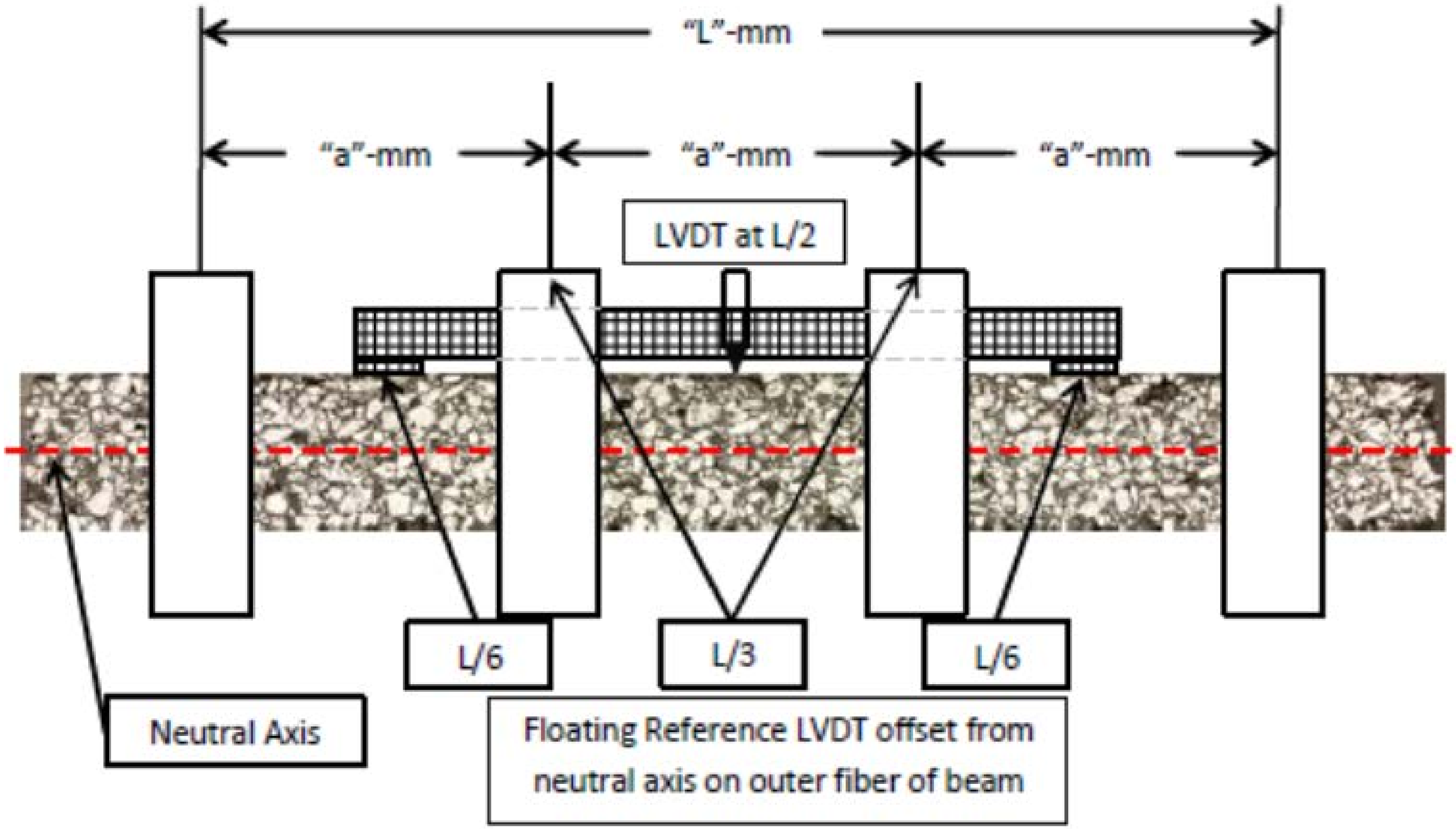


Diagram of Free Translation and Rotation Specified in Both AASHTO T-321 & ASTM D7460



Floating Reference LVDT with Targeting on Top of Beam to Tension Side of Beam displacement



Floating Reference LVDT

Floating reference LVDT on a FBF is defined as referencing the beam at the length between the outside frames divided by 6 (L/6). The L/6 location is ½ the distance between the outside frames and inside frames on a 4-point beam fixture.

- Reference point constantly changing through the duration of the test
  - Referencing the same object that you are breaking down
    - Pre-calculated displacement for the equation is changing due to the free floating reference point at the L/6 position.
  - Reference point is affected by multiple variables in a mix design
    - Aggregate size
    - Aggregate shape (flat, round, elongated, etc.)
    - Aggregate porosity
    - Binder grade
  - Reference point is affected by specimen response due to:
    - Temperature selection during FBF test
    - Mix design sag between the outside and inside clamps due to gravitational effects
    - Friction values of mix design during FBF testing
- LVDT is referencing the top of the beam
  - LVDT beam referenced location is in violation of AASHTO T-321-03 Section 8.2
  - Tensile side of beam when ran at 270° phase offset
  - Compressive side of beam when ran at 90° phase offset

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- Equation in AASHTO T-321-03 reference the neutral axis for calculations
  - Offset of ½ the distance from the neutral axis is not calculated for in the FBF equation in AASHTO T-321-03 section 9.1.2
  - Measurement of tensile and compression side of beam are different lengths
- Fabricator specific issues
  - Some old equipment without the repair of free horizontal translation on the H-frame
    - Beam specimen is being improperly strained between all clamping frames
  - Pendulum design for free horizontal translation at the two outside fixed frames
    - Estimated minimal variability, but it is additive
  - Applied motor force at each frame
    - Average force of motors
    - Area of clamp pads on sample
    - Average force per mm^2
- Operator specific issues
  - Running beam intentionally through zero
    - SHRP A-404 9.2.2 states: "The loading applied imparted tension only at the extreme fiber." (One direction loading)
  - Different operation of running beams through zero when measuring the contact points on the top or bottom of the beam weather you are fixed or floating will give you different values
  - Forcing beams through zero also induces healing, because you are putting energy back into the beam to compress what you have just stretched
  - Reduction in strain on beams being tested through zero is due to ½ strain tensile ½ strain compressive

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Combined Issues with Horizontal Fixtures

- Controller is not capable of referencing the origin start position once the test is initiated
  - H-Frame floats from its point of origin
- Horizontal beams will always have sagging between frames due to the viscoelastic nature of asphalt mixtures.
  - H-Frame lifts due to movement of L/2 origin start position during test until asphalt mixture in beam plateaus
    - Movement prior to start of test waiting for temperature stabilization

Thank you.