Advancing Disc Bearing Specifications

AASHTO T-2 Presentations

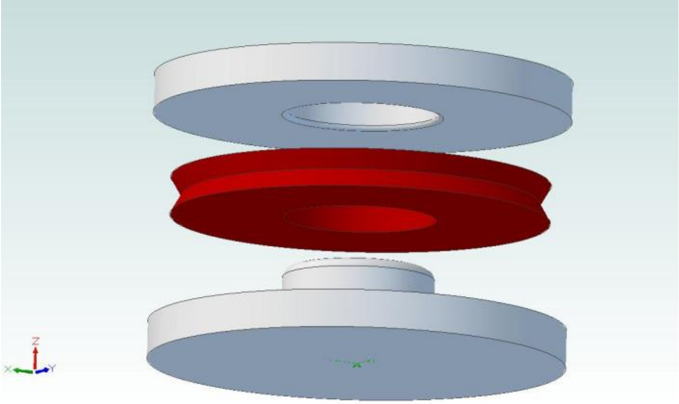
~~Austin TX, July 10, 2012~~

~~Columbus, OH   June 24, 2014~~

~~Minneapolis, MN, June 28 2016~~

~~Spokane WA, June 13 2017~~

Burlington VT, June 25 2018

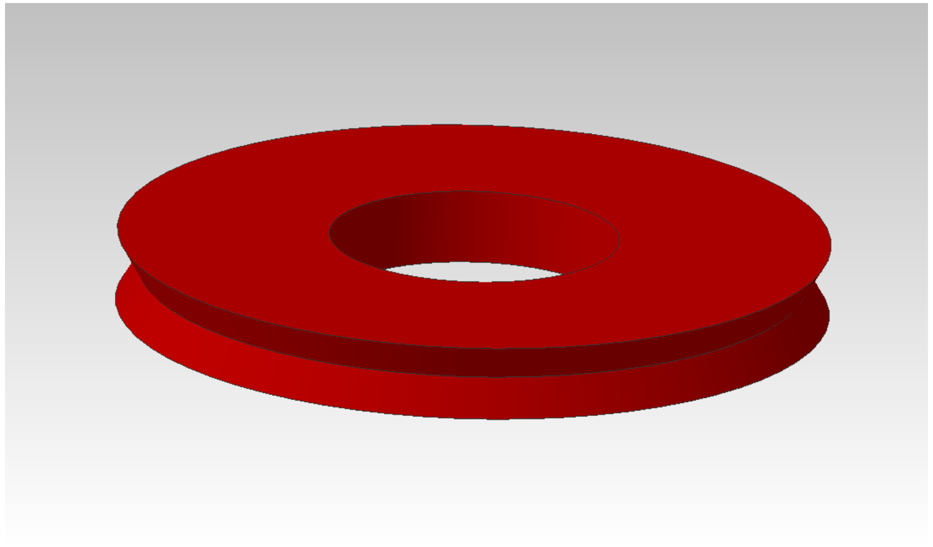


Ron Watson, RJ Watson

Richard Vanderwedge – RJ Watson

Paul Bradford - PB Engineering Consultant

OD = 12.00, ID = 4.88



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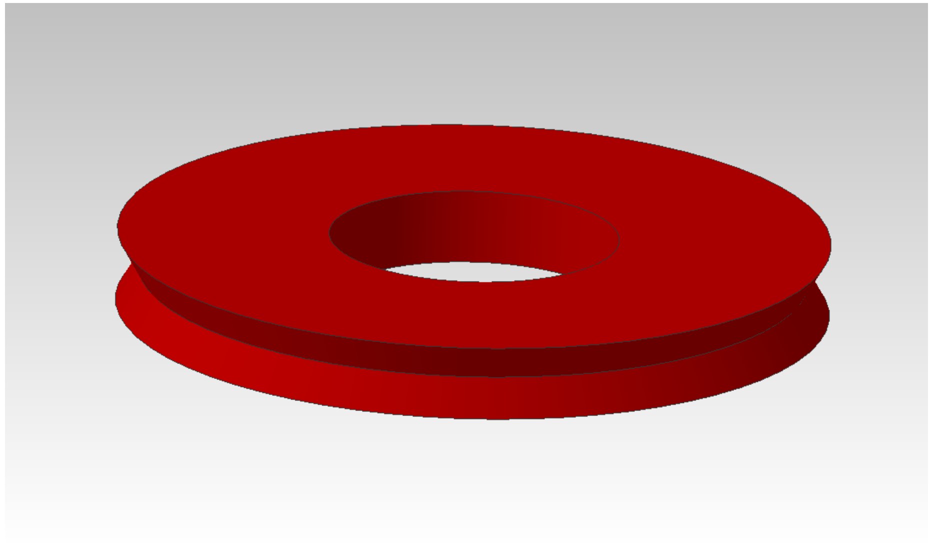

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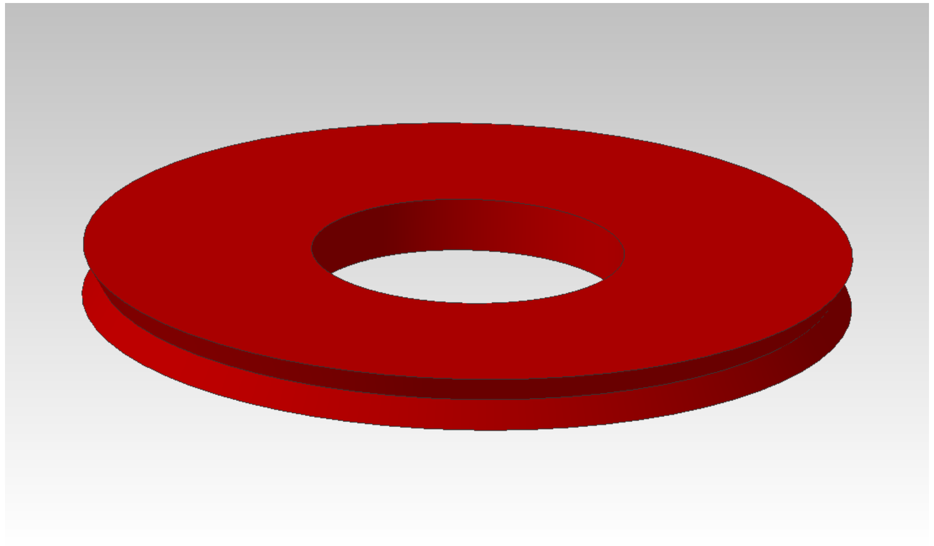

S=3.00

Motivations for Disc Bearing Design Update

1. The **design methodology has not evolved** as bearing types have.

2. Test, analysis, and field history support an increase in **allowables** that were first established 40 years ago.

3. **Short squat pads** can accommodate **higher stresses** than tall pads.

4. **Tall pads** can accommodate **more strain** than short pads.

- Simple
- Work within our range of experience

AASHTO 2017 Spokane – Report presented, overview given.

- Background
- Constraints explained
- Finite element analysis
- Friction
- Theoretical solutions
- Design Equations
- Production Bearing Tests
- Shape Factor Tests
- Disc Durometer Load Tests
- Design Examples
- Specifications

DISC DESIGN - METHOD B

Proposed update to AASHTO Design Specifications Section 14.7.8 – Disc Bearings. Method B includes the influence of shape factor. Method B represents a 20% increase over current limits. Field history, analysis, and testing are used to support this increase.

Design Method for Polyurethane Load Bearing Discs

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3.3 PHILOSOPHY

Two approaches can be taken to identifying design limits; absolute or relative. Past testing has shown that identifying an absolute limit state for the polyurethane disc along is difficult (Roeder, Stanton, & Taylor, NCHRP-298: Performance of Elastomeric Bearings, 1987), polyurethane material is quite robust, and every failure mode would have to be examined. Additionally, the

Safe Hypothesis – Current discs will successfully perform under a 20% increase in material duress

Based on

- Field history
- Project testing
- Research and Theory
- Facilitate implementation

This should be low risk >>>

Limits

Method A Service Limits

A.1 $\sigma_c \leq 5.00$ ksi

A.2 $\varepsilon_c \leq 0.10$

A.3 $\alpha_B \geq 0.0133$

Method B Service Limits

B.1 $\sigma_c \leq 7.00$ ksi

B.2 $\varepsilon_c \leq 0.14$

B.3 $\sigma_c \cdot \varepsilon_c \leq 0.72$

B.4 $\varepsilon_c \leq 0.24/S$ *ε_c = 0.10 for S > 2.4*

B.5 $\alpha_B \geq 0.015$

Proposed change is equivalent to a 20% increase in Stress & Strain

Method B Limits Explained

1. $\sigma_c \leq 7.00 \text{ ksi}$
2. $\varepsilon_c \leq 0.14$

Upper limits, design within our range of experience.
Individual, not simultaneous limits.

3. $S\varepsilon_c \leq 0.24$

Squat pads support higher stress but lower strain
Tall pads support higher strain, lower stress

4. $\sigma_c \cdot \varepsilon_c \leq 0.72$

Prevents simultaneous high stress & high strain in high durometer pads. Supports 20% overall change

5. $\alpha_B \geq 0.015$

Ensures a minimum level of disc flexibility

6. $S \geq 1.00$

Stability, range of experience

7. 80A-75D

Allowable durometer range

8. Durometer tolerance -3/+2

Must update calcs if not

Proposed change is equivalent to a 20% increase in Stress & Strain

How to Implement proposed changes into AASHTO specifications not discussed last year

2.1 METHOD B

The proposed specification is summarized in Table 2-1. The update might best be implemented by adopting a Method A and Method B approach, analogous to that of elastomeric bearings. Method A retains the heritage specification for users wishing a simpler yet more conservative approach (in most cases). Method B contains the proposed updated specifications.

Table 2-1:Method B specification in equation and limit forms

	Equation Form	Limit Form
B.1	$\sigma_c \le 7.0$	$\sigma_{UL} = 7.0$
B.2	$\varepsilon_c \le 0.14$	$\varepsilon_{UL} = 0.14$
B.3	$\sigma_c \varepsilon_c \le 0.72$	$(\sigma_c \varepsilon_c)_{UL} = 0.72$
B.4	$\varepsilon_c \le \begin{cases} \frac{0.24}{S} & S \le 2.40 \\ 0.10 \text{ if } & S > 2.40 \end{cases}$	$\varepsilon_{UL} = \max\left(\frac{0.24}{S},\ 0.10\right)$
B.5	$\alpha_B \ge 0.015$	$\alpha_{B\_LL} = 0.015$
B.6	$S \ge 1.00$	$S_{LL} = 1.00$
B.8	$75A \le Dur \le 75D$	$Dur_{LL} = 75A,\ Dur_{UL} = 75D$
B.9[1]	$\Delta Dur \ (+2, -3)$	$\Delta Dur_{LL} = 3,\ Dur_{UL} = 2$

[1] Discs with durometers outside these tolerances may still be used, but performance recalculation is required.

Specifications – 3 key changes

2.2 AASHTO Section 14.7.8 Changes

Changes that would allow for the proposed Method B in AASHTO Section 14;

1

1. Insert the following into section **14.7.8.3 – Elastomeric Disc**

The elastomeric disc may be designed according to Method A or Method B

$$\sigma_c = E_c \varepsilon_c \qquad (14.7.8.3\text{-}1)$$

$$E_c = Em \qquad (14.7.8.3\text{-}2)$$

The modulus factor m shall be of the form $a + bS^2$ as established through test and analysis by the manufacturer.

a,b	Empirical parameters
Dur	Disc durometer
E	Disc material apparent modulus
E_c	Compressive modulus
m	Modulus factor
S	Shape factor
α_B	Disc bearing rotation
ε_c	Average compressive strain
σ_c	Average compressive stress

2. Insert "**14.7.8.3.1 Method A**" after section 14.7.8.3 – Elastomeric Disc
3. Insert "**14.7.8.3.2 Method B**" after section 14.7.8.3.1 Method A

2 →

4. Insert into new section **14.7.8.3.2 Method B,** Table 2-1 (equation form) with footnotes
5. Include commentary for sections 14.7.8.3 – Elastomeric Disc and 14.7.8.3.2 Method B.

Commentary

5. Include commentary for sections 14.7.8.3 – Elastomeric Disc and 14.7.8.3.2 Method B.

C14.7.8.3 Method A and Method B for disc bearings are analogous to elastomeric laminated bearing Method A (14.7.6) and Method B (14.7.5). Method A is a simpler, heritage approach. Method B is a more refined method allowing for greater design flexibility.

The design form of $E_c = Em$, with $m = a + bS^2$ in lieu of more complicated expressions simplifies design, encourages the manufacturer to test and analyze in a similar configuration as that being used, and provides a standard context for comparisons between discs of various compounds, shape factors, *ID/OD* ratios, etc.

It may be difficult to establish *E* as purely a material property. The intent here is for *E* to serve as "mostly" a material property, i.e. an apparent material modulus. Engineering judgment is required. For example, depending on the behavior of *E* at various data points, it may make sense to reduce the averaged expression $E_c = 10\left(1.1 + 1.2S^2\right)$ to $E_c = 11\left(1 + 1.1S^2\right)$. Conversely, simplifying $E_c = 10\left(2.0 + 1.2S^2\right)$ to $E_c = 20\left(1 + 0.60S^2\right)$ would violate the intent of *E* being mostly a material property.

C14.7.8.3.2 Method B includes shape factor effects, such as the fact that thin discs can accommodate higher loads but lower strains than tall discs. Higher allowable stresses and strains than found with Method A are allowed, however, unlike Method A these are not permitted to occur simultaneously. Method B has been tuned to represent a 20% increase in strain energy and shear stress over Method A. Method B uses the *OD* and *ID* of the disc to compute shape factor and area. A minimum shape factor constraint serves as a simple stability check. The inclusion of durometer tolerances and the requirement that *m* be verified by test and analysis help form a stronger tie between disc field performance and design. A QC compression-deflection test requirement for Method B has been added.

Add to Construction Specifications: **18.3.4.6 – Compression-Deflection Test**

3

Disc bearings designed using Method B shall include compression-deflection testing in accordance with AASHTO standard M 251 Section 9.1. In lieu of the specified 75 psi/minute loading, loading may be applied at a rate not to exceed 20% of the full load/minute if a 5 minute hold is used at the initial and final loadings. Certified results shall be provided to the Engineer.

Construction - Other

18.3.4.4.4—Proof Load Test

Sampled bearings shall be short-term load-tested to 150 percent of the specified rated capacity at 0.02 rad. If the size of the bearing prohibits adequate testing with available equipment, the Owner may specify a test on one (1) scaled down bearing with comparable requirements. The load shall be held for 5 minutes, removed, then

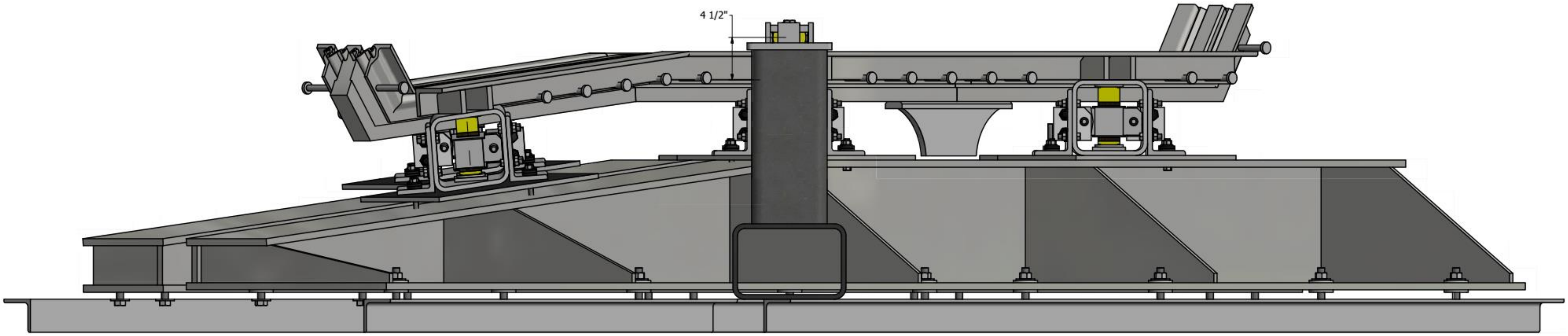
Section 18.3.4.4.4 – Change the first sentence to Sampled bearings shall be short-term load-tested to 150 percent of the specified rated capacity at the larger of *0.020 radians or the design service rotation.*

Section 18.3.4.4.4 – Eliminate 2nd sentence; "If the size of the bearing prohibits adequate testing with available equipment the Owner may specify a test on one (1) scaled down bearing with comparable requirements".

Section 18.9 - Change A307 to ASTM F1554

OMV Test

AASHTO A19 Opening Movement Vibration



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NCHRP REPORT 467

Performance Testing for Modular Bridge Joint Systems

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NATIONAL ACADEMY PRESS
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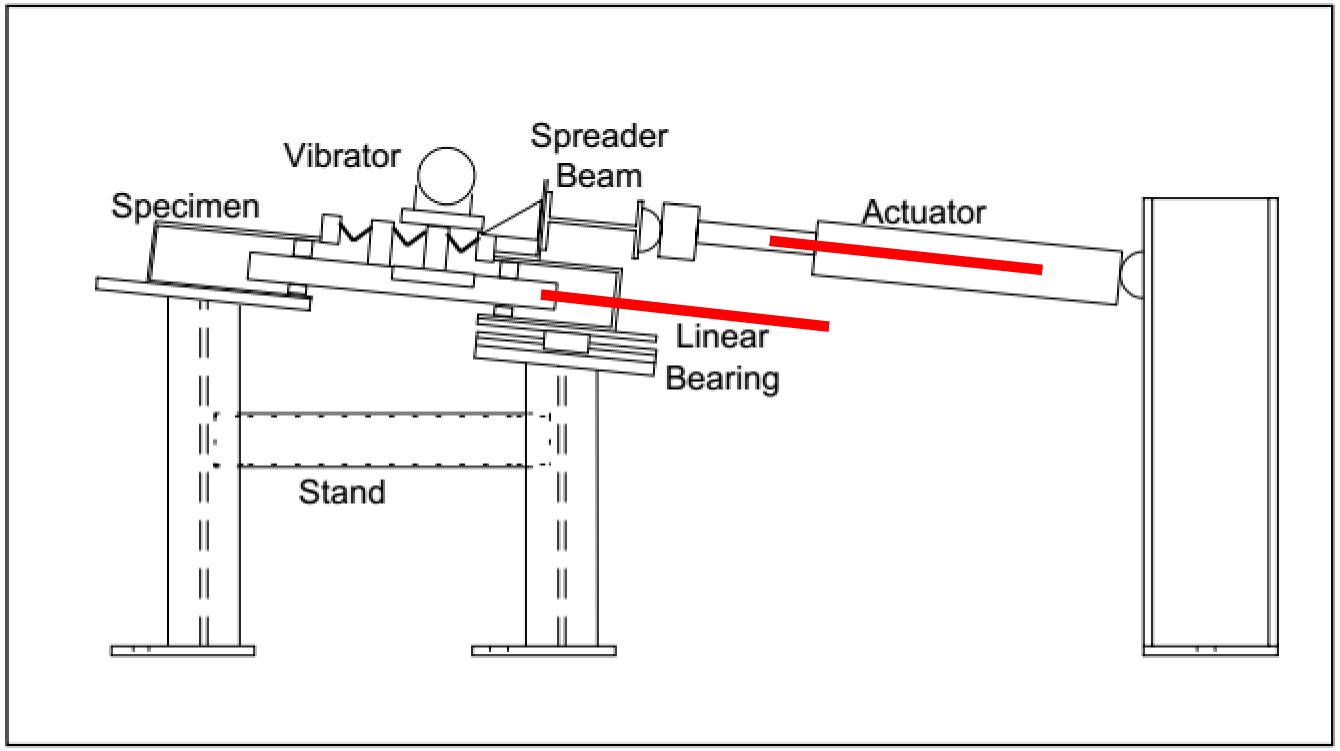


Figure 2.19. Side view OMV test set up.

TABLE 2.14 Durability of test specimens

Specimen	Time 1st Fail	Durability Rank
6	76 hrs 6 min	1
3	33 hrs 40 min	2
2	26 hrs 35 min	3
4	21 hrs 35 min	4
1	4 hrs 35 min	5
5	50 min	6

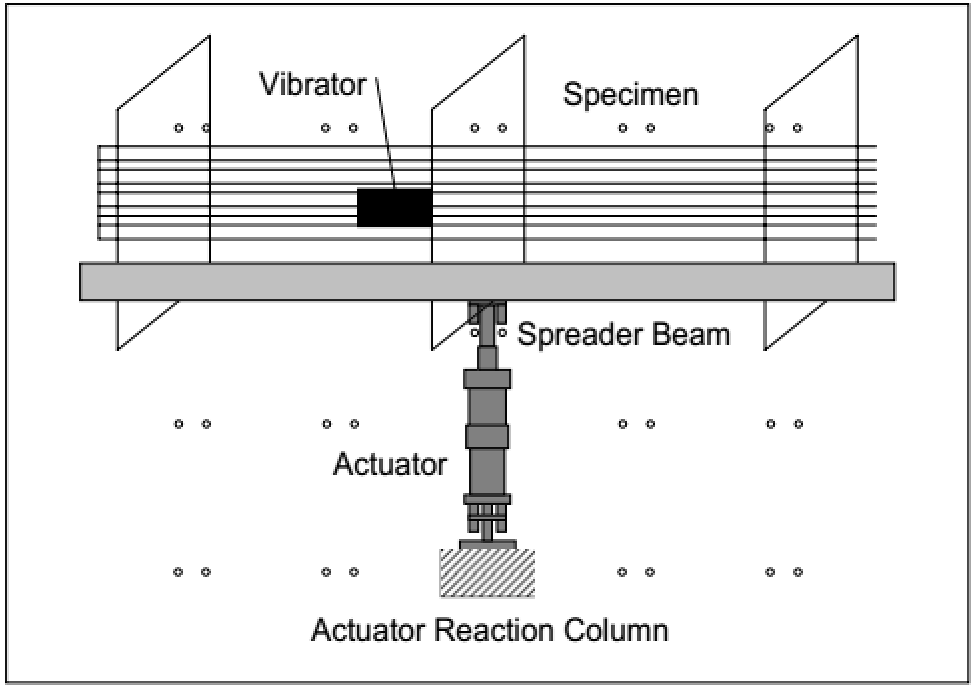


Figure 2.20. Plan view no skew OMV test set up.

that rode in the grooves of the rail. A 25.4-mm (1-in.) plate was bolted to the top of the carriage. The support box connected to the linear bearing was then fillet welded to this plate, allowing longitudinal movement. Figure 2.24 shows the linear bearing placement in relation to the stands and the specimen.

At first, it was attempted to place a linear bearing at each

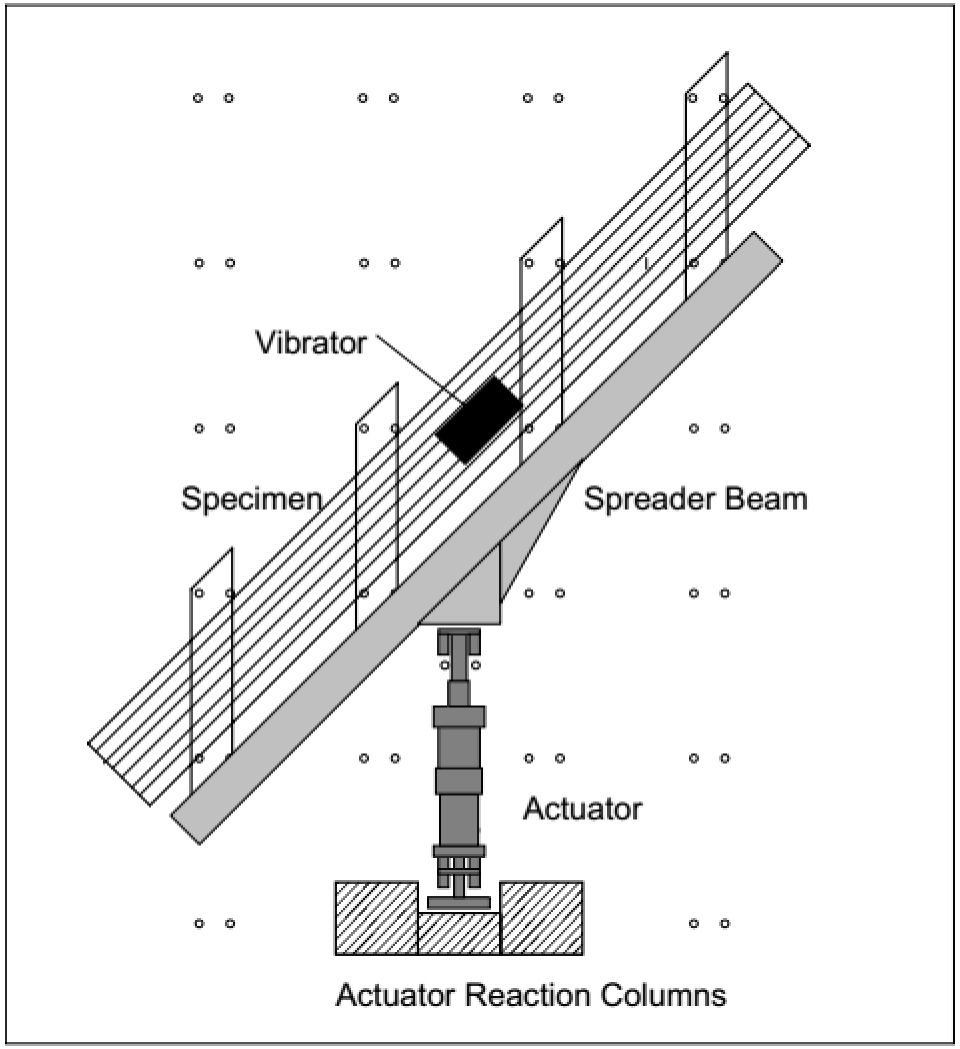
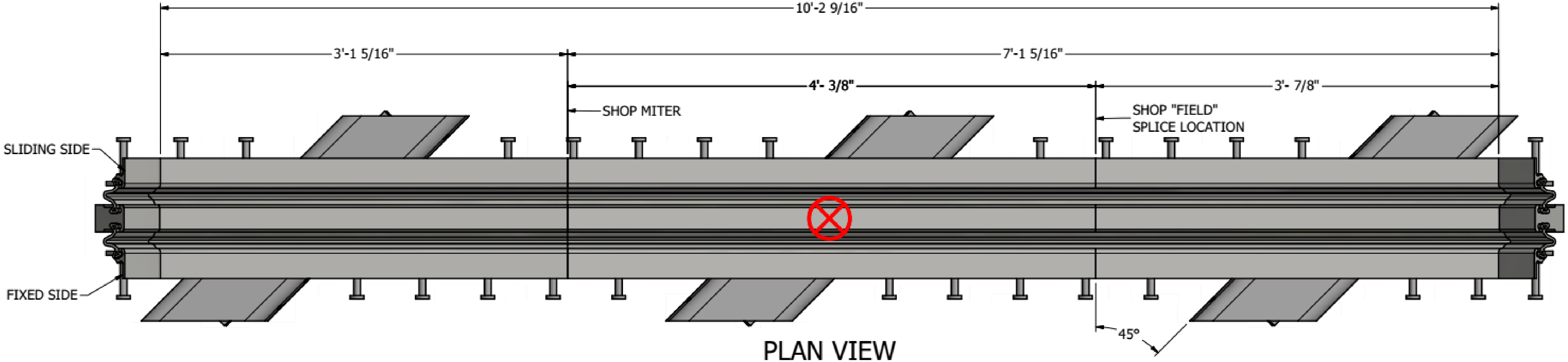


Figure 2.22. Plan view 45-deg skew OMV test set up.


STM205980AA
STM205980AA
STM205980AA
3/8" J-FLEX 10K JACK HOSE 10,00
2

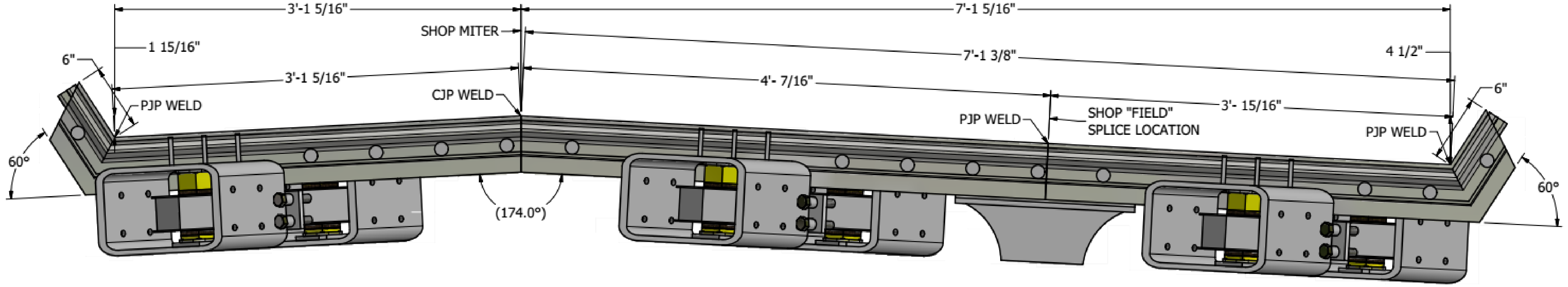
Geometry Constraints

- MBJS with any number of support boxes;
- MBJS with from one to $n + 4$ centerbeams (where n is the number of centerbeams in the configuration that was tested) and the associated varying support bar spans;
- MBJS with any centerbeam span less than 1.25 times the span that was tested;
- MBJS with smaller skew;
- MBJS with a lower angle of upturn or no upturn;
- MBJS with a flatter vertical crown or less of a horizontal kink; and
- MBJS with centerbeams or edgebeams with cross-sectional area that is from 75 percent to 125 percent of the cross-sectional area that was tested.



PLAN VIEW

STM205980AZ: STM-600 OMV TEST MBJS



Vehicle pulse frequency

$V := 60\cdot\frac{63360}{3600} = 1056$ Vehicle velocity, ips

$L_T := 10$ Tire patch length

$bm_w := 2.50$ Beam width

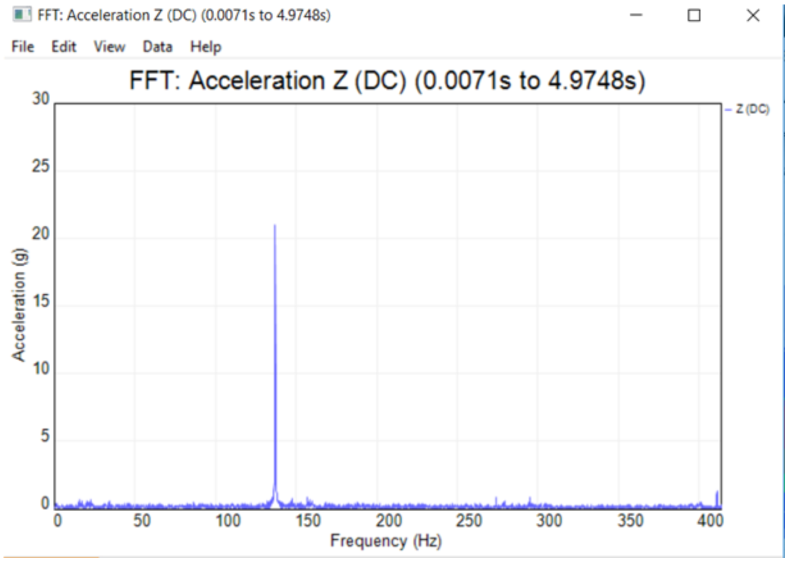
$t_D := \frac{bm_w + 10}{V} = 0.012$ Tire pulse duration

$f_v := \frac{1}{2t_D} = 42.24$ Vibration frequency

Tire pulse train frequency << 1.0 Hz

TABLE A-1 Vibco SVRLS 8000 specifications

Air press		Vib per sec	Force	
(kPa)	(psi)		(N)	(lbs)
551.6	80	141.7	33900	7625
620.6	90	145	35600	8000
689.5	100	158	42500	9550



WBA measured 137 Hz at 80 psi

AASHTO A19

5.1.1.4 Vibrator to apply simulated traffic loads. The vibrator shall produce a force at a frequency of between 70 and 100 Hz (total force range of at least 44 kN (be used, however a Vibco SVRLS 8000 pneumatic high-frequency vib

OMV & SPO 2019?

Thank you