DESIGN METHOD FOR ELASTOMERIC BEARINGS FOR STEEL TUB GIRDER BRIDGES

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Biography

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Mr. Bradberry is the Support Branch Manager for the Technical Services Section of the TxDOT Bridge Division. He leads a small band of engineering professionals performing ancillary structure (sign, light and traffic signal supports) design and support; recommending, evaluating, and developing engineering software, and providing end user software support; and, occasionally designing and/or rating bridges. He provides technical expertise in fiber reinforced polymer (FRP) reinforcement for concrete, design of elastomeric bearings, shear of structural concrete and design of prestressed concrete members. He has over nineteen years of bridge engineering experience, including four years as a supervisor.

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Mr. Medlock is Director of the Bridge Technical Services Section of the TxDOT Bridge Division. He oversees geotechnical structures, traffic structures, bridge railing, bridge standards, special projects, and structural software. He has seventeen years experience in design and fabrication of transportation structures.

Summary

Elastomeric bearings are an excellent choice for bridge applications because they are low cost, easy to install, and very durable. However, when applied to the movement and load demands of typical curved tub girder bridges elastomeric bearings cannot satisfy current AASHTO design provisions. Research projects sponsored by TxDOT and NCHRP and performed in the 1990s at the University of Texas at Austin found that excessive conservatism in the AASHTO design provisions for elastomeric bearings unnecessarily restrains their use. TxDOT engineers made use of these research findings in the design of bearings for a typical curved steel tub girder bridge demonstrating that elastomeric bearings were more suitable for that project than the traditional choice of pot and disc bearings. Therefore, TxDOT engineers developed a design method based on the research results and successfullly used this design method on direct connectors at the IH35 / US290 interchange in Austin, Texas, which opened in 2001. This paper presents highlights of the TxDOT elastomeric bearing design procedure for consideration by other bridge engineers.

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by

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INTRODUCTION

Texas Department of Transportation (TxDOT) bridge engineers prefer elastomeric bearings to other bearing types because elastomeric bearings are generally the least expensive and easiest to maintain. Therefore, in the late 1990s TxDOT bridge engineers designed steel laminated elastomeric bearings to support steel trapezoidal (tub) girder bridges. TxDOT-sponsored research had indicated that it should be possible to use elastomeric bearings in such bridges, but the design of such bearings could not be accomplished under the governing AASHTO provisions due to restrictive rotation limits and slip controlled elastic thickness requirements (1). Additionally, TxDOT engineers preferred the higher stress limits of Method B of the AASHTO provisions but not the associated additional battery of material tests. Results of TxDOT and NCHRP sponsored research were employed to justify design stresses exceeding those of Method A without raising the bar on material test requirements (2, 3). The TxDOT-sponsored research provided a basis for pushing certain limitations of the AASHTO design specifications to demonstrate that elastomeric bearings could indeed handle typical steel tub girder loads and movements. The direct connectors of the US 290 / IH 35 interchange built in north Austin, Texas, in 2000 demonstrated the feasibility of using elastomeric bearings for steel tub girders bridges. Subsequent to the construction of these structures, TxDOT engineers published a design method to facilitate the use of elastomeric bearings on other Texas steel tub girder bridges by others bridge engineers (4).

BEARING DESIGN FACTORS

TxDOT bridge engineers consider the following factors in the design of bearings for steel tub girder bridges:

- Thermal and time-dependent bridge expansion and contraction
- Rotations
- Compression (minimum, maximum, and sustained)
- Slip
- Fabrication
- Pedestal capacity
- Superstructure restraint
- Force transfer from superstructure to substructure
- Stability

These factors are considered and balanced while designing the bearings to serve their primary role—to transfer forces and accommodate movement between superstructure and substructure while maintaining stability.

USE OF ELASTOMERIC BEARINGS IN TEXAS

TxDOT bridge engineers have used elastomeric bearings for prestressed beam bridges since the 1950s (with the first installed in 1957) and for steel beam bridges since the 1960s, for a total of over 500,000 installations. AASHTO first incorporated elastomeric bearings into the design specifications in 1958. The elastomers used in these bearings include both neoprene and natural rubber. TxDOT engineers have found that elastomeric bearings are consistently cost-effective, easy to install, and easy to maintain. With the exception of bearings installed in one period in the 1990s, elastomeric bearings have provided excellent performance.

The performance exception involved natural rubber bearings that "walked out" on a number of bridges. In the mid 1990's TxDOT-sponsored research determined that certain natural rubber bearings slipped repeatedly under cyclic expansion and contraction when excessive paraffin, added to avoid surface cracking associated with ozone attack, migrated to the bearing surface and reduced the bearing pad friction coefficient (5). This problem was solved by replacing the failed ("walked out") bearings with equivalent neoprene bearings and by disallowing further use of natural rubber bearings.

Generally, steel tub girder bridges in Texas are curved direct connectors with relatively long spans (150' to 300') and continuous units (up to 900' or more). Design requirements for such bridges, which transmit relatively high loads and movements, generally indicate a need for high-load, multi-rotational (HLMR) bearings such as pot or disk bearings. To push this envelope, TxDOT explored the basis of the AASHTO design provisions that heretofore have precluded the use of elastomeric bearings in such applications, by sponsoring research to determine if the limitations could be overcome.

SUMMARY OF ELASTOMERIC BEARING RESEARCH CONDUCTED AT UT AUSTIN

Exploring how the AASHTO specification limits on elastomeric bearing design could be relaxed, and corresponding material testing requirements curtailed, University of Texas at Austin (UT Austin) researchers considered the combined effects of higher loads and rotations, increased hardness and increased shape factor. They found that effective designs could be achieved with low hardness and increased shape factor. A brief summary of the research findings follows and the detailed findings are available in the research reports (2, 3):

- Shear modulus can be estimated from hardness readings, but precise shear modulus can only be determined by testing (note that modulus rather than hardness is a direct design parameter).
- Bearing manufacturers fabricate with good geometry control and can consistently reproduce the same bearing compound such that the same shear modulus will be achieved to within +/- 5%.
- Increase of hardness from 55 to 70 durometer increases shear stiffness by 25%, compressive stiffness by 15%, and rotational stiffness by 43%. Associated performance trade-offs include increased force transfer, higher friction needed for restraint, reduced rotational capacity, and higher shear stiffness loss under fatigue loading.
- Increase of shape factor from 6.26 to 10.96 increases shear stiffness by 7%, compressive stiffness by 150%, and rotational stiffness by 22%, and decreases rotation capacity by 60%.
- Increase of compressive stress from 550 psi to 1100 psi lowers shear stiffness by 6% and increases rotation stiffness by 10% and rotational capacity by 120%.
- Much higher rotations can be effectively achieved than currently allowed by AASHTO, in part by tolerating a limited amount of lift-off (with no up-lift).
- Bearing manufacturers prefer a minimum grade 40 steel shim thickness of 0.1064" to preclude damage during vulcanization, and the research found no justification for thicker material.
- The AASHTO β-factor is conservative based on minimal bulging observed in tests.
- The assumed directions of movement at the ends of steel tub girder units may not be accurate for highly curved, especially compound curved (or curved and tangent), tub girders. Guides at these and other bearing locations intended to restrain movement to a pre-determined direction might not remain in place, so they should not be relied upon. Slippage should not be progressive if the elastomer thickness is properly designed, excessive amounts of paraffin are not present into the pad, and the pad is not tapered. Any such slippage (preferably at the pad beam/"sole plate" interface) will re-set the pad making further

shear strain accumulate predominately in the reverse direction. Alignment of the ends of moderately skewed tub girder units, are best maintained by properly designing and detailing the elastomeric bearings, rather than trying (perhaps unsuccessfully) to restrain the structure using guides.

ROTATIONAL CAPACITY

The TxDOT-sponsored research finding of expanded rotational capacity beyond that allowed by AASHTO facilitated the use of elastomeric bearings for curved steel tub girder bridges. To determine the effect of compressive stress on rotational stiffness and capacity, elastomeric bearings having the following combined parameters were subject to rotations of up to 1.9 degrees (0.033 radians) each:

- 50 and 70 durometer (nominal)
- 3 and 6 shims
- flat, 4% taper, and 6% taper
- 550 and 1100 psi

For purposes of the research, rotation capacity was defined as the point where the moment-rotation relationship became non-linear. Tests were closely monitored to determine the point of lift-off. The rotational capacity tests revealed the following:

- Doubling the compressive stress from 550 ksi to 1100 ksi increased rotational stiffness by 10.8% on average and increased rotation capacity by 120% on average.
- Even under very significant rotations (up to 0.0293 radians), only 3/4" of lift-off occurred (where the lift-off was defined as the supported structure rotating off of the edge of the bearing for the indicated horizontal distance measured perpendicular to the direction of rotation). No detrimental effects to the pad were noted for the observed lift-off. Up to 20% lift-off was deemed by test to be permissible.
- No uplift (defined as any portion of the pad pulling away from the bearing seat) occurred.
- Increasing hardness had a negligible effect on rotation capacity of the three shim bearings but reduced rotation capacity by 38.2 % for the six shim bearings.
- Increasing the shape factor from 6.26 to 11.0 reduced rotation capacity of 54 durometer material by 51% and of 69 durometer material by 70.4%.
- Tapered pads had higher rotation capacity than non-tapered pads.
- Generally, parallel orientation of shims produced higher rotation capacities than radial shim orientation.

These findings indicate that higher rotations and higher strains can be accommodated with balanced use of softer material, low shape factors, and increased compressive stress. The researchers recommended removal of AASHTO limitations which preclude lift-off, and use of total shear strain as a criterion to limit the stresses from all sources. According to the UT Austin researchers, the AASHTO limitations on allowable stress, rotation capacity, and slip, and the associated more rigorous testing requirements of Method B, were derived from a body of progressively more constrictive applied elastomeric bearing research performed for NCHRP from 1970 through 1987 (6, 7, 8). Using the liberalized recommendations of the TxDOT-sponsored research, the bridge design engineer may design a serviceable bearing to rotation limits of 0.024 radians at 550 psi and 0.030 radians at 1100 psi, if assumed lift-off does not exceed 20%; beyond this, the designer can simply ensure that the portion of the bearing remaining loaded can stably carry the design compressive stresses while keeping the average compressive stress within a reasonable allowable limit.

BEARINGS FOR US 290 / INTERSTATE 35 INTERCHANGES

US 290 / IH 35 Interchange in North Austin, Texas

TxDOT engineers used the UT Austin research findings as the basis for developing the design procedure used for the elastomeric bearings of the four tub girder direct connectors of the US 290 / IH 35 interchange in north

Austin. The six continuous units of the four direct connector bridges are summarized in Table 1. The elastomeric bearing pad designs are summarized in Tables 2 and 3.

Two of the direct connectors were instrumented by UT Austin researchers to assess the structural behavior of the steel tub girders (9). The behavior of the elastomeric bearings was not included in the scope of that study. However, the four direct connectors have been in service since early 2001, demonstrating over 4 ½ years of successful performance of elastomeric bearings supporting curved steel tub girder bridges.

Table 1. Steel Tub Girder Bridges at US290 / IH35 (In North Austin)

DC	Length (ft.)	Spans (ft.)	Curve (degrees)
Z1	493.00	151.50–290.00–252.50	12.73
Z2	279.55	146.00–139.55	12.73
K	578.00	168.00–242.00–168.00	10.00
M1	698.43	146.43–202.00–202.00–148.00	8.00
M2	453.58	265.00–189.58	8.00
[1]Y	880.00	210.00–230.00–230.00–210.00	0.00 to 12.50

[1]One end of Ramp "Y" was skewed 12.43 degrees

Table 2. Elastomeric Bearing Pad Design Summary – Part I

Bent (Loc)	No. of Brngs Req'd (ea)	Brng Type	Brng Pad Plan Dim (in)	Beveled Slope Plate (in)	Sole Plate Bevel: Cross-Slope + ft/ft Looking Fwd Sta	Sole Plate Bevel: Grade + ft/ft Fwd Sta to Right	Sole Plate Avg Thk (in)	[2]No. of "t" (ea)	[2]Layer Thk "t" (in)	Unloaded "T" (in)	[3]Loaded "T" (in)	Total Unloaded Bearing Height (in)	Total [3]Loaded Bearing Height (in)
13Z (FD)	2	T-EE1	13 X 20	20 X 25	-0.025	0.033	2.250	7	0.500	5.207	5.070	7.457	7.320
14Z	2	T-IE1	18 X 36	22 X 38	-0.060	0.033	2.750	4	0.500	3.348	3.258	6.098	6.008
15Z	2	T-IF1	18 X 36	20 X 38	-0.060	0.007	2.750	4	0.500	3.348	3.242	6.098	5.992
16Z (BK)	2	T-EE1	13 X 20	20 X 25	-0.060	-0.014	2.250	7	0.500	5.207	5.062	7.457	7.311
16Z (FD)	2	T-EE1	13 X 20	20 X 25	-0.060	-0.015	2.250	7	0.500	5.207	5.077	7.457	7.328
17Z	2	T-IF1	18 X 36	20 X 38	-0.060	-0.034	2.750	4	0.500	3.348	3.253	6.098	6.004
18Z (BK)	2	T-EE1	13 X 20	20 X 25	-0.060	-0.054	2.250	7	0.500	5.207	5.078	7.457	7.328
17K (FD)	2	T-EE1	13 X 20	20 X 25	0.024	0.002	2.250	7	0.500	5.207	5.066	7.457	7.315
18K	2	T-IF2	21 X 36	23 X 38	0.060	-0.003	2.750	4	0.500	3.348	3.237	6.098	5.987
19K	2	T-IE2	21 X 36	25 X 38	0.060	-0.011	2.750	4	0.500	3.348	3.256	6.098	6.006
20K (BK)	2	T-EE1	13 X 20	20 X 25	0.060	-0.016	2.250	7	0.500	5.207	5.066	7.457	7.316
1Y (FD)	2	T-EE2	14 X 27	21 X 31	-0.025	0.069	2.250	7	0.500	5.207	5.089	7.457	7.338
2Y	2	T-IE2	21 X 36	25 X 38	-0.025	0.056	2.750	4	0.500	3.348	3.254	6.098	6.004
3Y	2	T-IF2	21 X 36	23 X 38	-0.060	0.029	2.750	4	0.500	3.348	3.245	6.098	5.995
4Y	2	T-IE2	21 X 36	25 X 38	-0.060	0.003	2.750	4	0.500	3.348	3.242	6.098	5.992
5Y (BK)	2	T-EE2	14 X 27	21 X 31	-0.036	-0.021	2.250	7	0.500	5.207	5.028	7.457	7.278
10M (FD)	2	T-EE1	13 X 20	20 X 25	0.056	0.039	2.250	7	0.500	5.207	5.067	7.457	7.317
11M	2	T-IE2	21 X 36	25 X 38	0.056	0.039	2.750	4	0.500	3.348	3.278	6.098	6.028
12M	2	T-IF2	21 X 36	23 X 38	0.056	0.022	2.750	4	0.500	3.348	3.239	6.098	5.989
13M (BK)	2	T-EE2	14 X 27	21 X 31	0.056	-0.001	2.250	7	0.500	5.207	5.049	7.457	7.299
13M (FD)	2	T-EE1	13 X 20	20 X 25	0.056	-0.001	2.250	7	0.500	5.207	5.113	7.457	7.364
14M	2	T-IF3	23 X 36	25 X 38	0.056	-0.018	2.750	5	0.500	3.968	3.837	6.718	6.587
15M	2	T-IE3	23 X 36	27 X 38	0.056	-0.048	2.750	5	0.500	3.968	3.856	6.718	6.605
16M (BK)	2	T-EE1	13 X 20	20 X 25	0.016	-0.069	2.250	7	0.500	5.207	5.055	7.457	7.305

[2]In addition to the interior layers indicated in the this table, each bearing pad has two 3/8" elastomeric cover layors.

[3]Load assumed in the calculation of pad and bearing heights includes instantaneous dead load only.

Figures 1 shows portions of the direct connectors of the competed Interchange. Figure 2 shows the end of one of the tub girders resting on the relatively tall end bearing at an intermediate construction phase. Some of the bearings in the finished structure are highly visible, including the bearings shown in Figures 3 thru 5. It seems that a permanent shear deformation was imposed on the bearings shown in Figures 3 and 4 during the splicing of the tub girders. Nevertheless, the bearings have not shown any signs of slippage. The bearings that were designed to resist calculated uplift are less accessible. TxDOT bridge inspection engineers have not yet inspected these tub girder bearings, but there is no indication that slippage or uplift has occurred.

Table 3. Elastomeric Bearing Pad Design Summary – Part II

Bent (Loc)	Max Allow Expn Lgth (ft)	Min Total Load (kips)	Max Dead Load (kips)	Max Total Load (kips)	Max Horz Force (kips)	Req'd Rotation Capacity (radians)	[4]Brng Dist (in)	[5]Req'd Min Bent Offset (in)	Sole PL Corner Thk B1 (in)	Sole PL Corner Thk B2 (in)	Sole PL Corner Thk B3 (in)	Sole PL Corner Thk B4 (in)
13Z (FD)	397	83	171	286	19	0.019	16.00	NONE	2.23	1.60	2.27	2.90
14Z	265	384	594	784	34	0.006	0.00	NA	3.52	1.24	1.98	4.26
15Z	fixed	389	590	779	34	0.006	0.00	NA	3.82	1.54	1.68	3.96
16Z (BK)	344	65	183	309	22	0.020	16.00	NONE	3.14	1.64	1.36	2.86
16Z (FD)	321	61	159	288	18	0.016	16.00	NONE	3.15	1.65	1.35	2.85
17Z	fixed	366	513	691	30	0.005	0.00	NA	4.23	1.95	1.27	3.55
18Z (BK)	252	60	158	286	18	0.015	16.00	NONE	3.54	2.04	0.96	2.46
17K (FD)	409	75	177	317	24	0.013	16.00	NONE	1.93	2.53	2.57	1.97
18K	fixed	489	796	1013	40	0.010	0.00	NA	1.64	3.92	3.86	1.58
19K	265	489	796	1013	40	0.010	0.00	NA	1.74	4.02	3.76	1.48
20K (BK)	410	75	177	316	24	0.013	16.00	NONE	1.66	3.16	2.84	1.34
1Y (FD)	410	154	222	346	31	0.019	17.00	NONE	1.92	1.14	2.58	3.36
2Y	265	594	816	1076	47	0.008	0.00	NA	2.53	1.58	2.97	3.92
3Y	fixed	416	723	967	46	0.006	0.00	NA	3.55	1.27	1.95	4.23
4Y	265	559	949	1187	49	0.011	0.00	NA	3.85	1.57	1.65	3.93
5Y (BK)	408	54	373	540	32	0.024	14.50	-0.8705	3.03	1.91	1.47	2.59
10M (FD)	342	75	176	300	23	0.014	16.00	NONE	1.16	2.56	3.34	1.94
11M	265	391	545	731	37	0.006	0.00	NA	1.19	3.32	4.31	2.18
12M	fixed	546	778	987	42	0.011	0.00	NA	1.43	3.56	4.07	1.94
13M (BK)	355	95	321	473	26	0.021	16.00	NONE	1.39	3.13	3.11	1.37
13M (FD)	slider	-22	103	219	23	0.006	16.00	NONE	1.56	2.96	2.94	1.54
14M	fixed	544	815	1033	43	0.015	0.00	NA	1.91	4.04	3.59	1.46
15M	313	604	945	1177	45	0.011	0.00	NA	2.34	4.46	3.16	1.04
16M (BK)	410	87	194	329	25	0.016	16.00	-2.5	2.75	3.14	1.75	1.36

[4]Maximum Bearing Distance used is controlled by required distance to CL of end diaframs for worse case of beam grade.

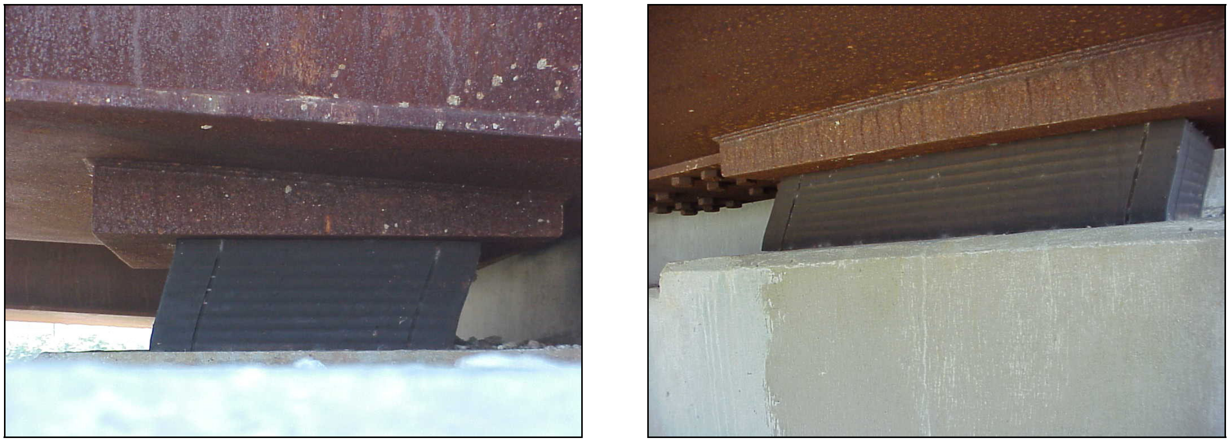
[5]"Required Min Bent Offset" is that of CL superstructure joint and CL bent needed to provide at least four (4) inches clear between edge of bearing pad and edge of pedestal. A negative value indicates that CL bent is to be located back station of superstructure CL joint.

(b)

(a) (c)

Figure 1. Views of the US 290 / IH 35 Interchange, Showing (a) Direct Connector "Z " From Below, (b) Direct Connector "Z" From the East, and (c) Direct Connectors "Y", "M", and "K" (From Nearest to Most Distant, Respectively) From the South; Under Construction (view "a"; 2001) and In Service (views "b" and "c"; 07-06-2005).

Figure 2. US 290 / IH 35 Interchange, Direct Connector "Z", Steel Tub Girder Unit #1 End Bearing, Under Construction (03-07-2000).



(a) (b)

Figure 3. US 290 / IH 35 Interchange, Direct Connector "Y", South End of Unit, Showing West End Bearing, Construction Induced Shear Deformation, (a) Longitudinal and (b) Transverse; In Service (08-06-2002).

(a) (b)

Figure 4. US 290 / IH 35 Interchange, Direct Connector "Y", South End of Unit, Showing (a) East End Bearing and (b) West End Bearing; Construction Induced Longitudinal and Transverse Shear Deformation; In Service (07-06-2005).

Figure 5. US 290 / IH 35 Interchange, Direct Connector "Y", West Bearing at First Interior Bent from South End of Tub Girder Unit; In Service (07-07-2005).

US 71 / US 290 / IH 35 Interchange in South Austin, Texas

Similarly, elastomeric bearings were used for the curved steel tub girder direct connectors of the companion US 290 / US 71 / IH 35 interchange in south Austin that has been under construction since 2001. This project demonstrated the successfully use of TxDOT-developed design procedure by a separate design office (a consultant).

The photographs in Figures 6 thru 8 were taken in April 2002 during construction of the interchange. Figure 8 shows an elastomeric bearing supporting very high loads.

Figure 6. Steel Tub Girder Being Lowered in Place at an Interior Bent, IH 35 / US 71 / US 290 Interchange in South Austin, Texas (note the beveled sole plate); During Construction (April 27, 2002).

Figure 7. Steel Tub Girder and Bearing in Place at an Interior Bent, IH 35 / US71 / US290 Interchange in South Austin, Texas (note the beveled sole plate); During Construction (April 28, 2002).

Figure 8 Elastomeric Bearing Supporting a Steel Straddle Bent Supporting Four Steel Tub Girders, IH 35 / US 71 / US 290 Interchange in South Austin, Texas; During Construction (April 27, 2002).

All but the south IH 35 to east US 71 direct connectors of the interchange were under traffic when the photos shown in Figures 9 thru 14 were taken in September 2005. The bearing shown in parts a, b, and c of Figure 11 is damaged because the sole plate did not completely cover the bearing when the tub girder was seated. There is a significant amount of uplift and elastomer damage near in the region of the exposed edge. This bearing will likely be replaced prior to opening the bridge to traffic.

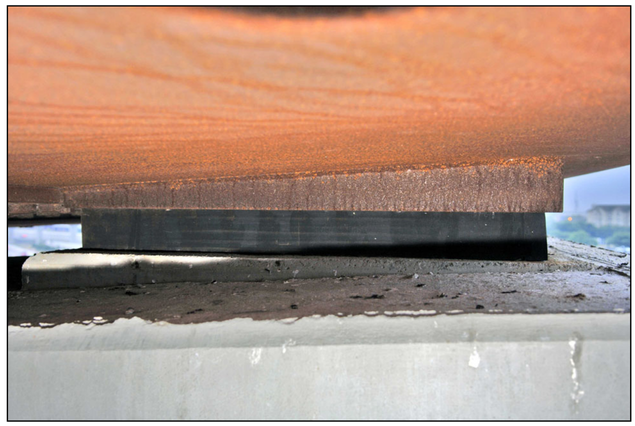
Figure 9. South IH 35 to East US 71 Direct Connect Bridge (Lower Structure); Ready for Service (September 12, 2005) and East US 71 / US 290 to North IH 35 Direct Connect Bridge (Upper Structure); In Service (September 12, 2005).

(a)

(b)

Figure 10. East End of South IH 35 to East US 71 / US 290 Direct Connect Steel Tub Girder Unit, Showing (a) South End of North Bearing and (b) North End of South Bearing; Ready for Service (09-12-2005).

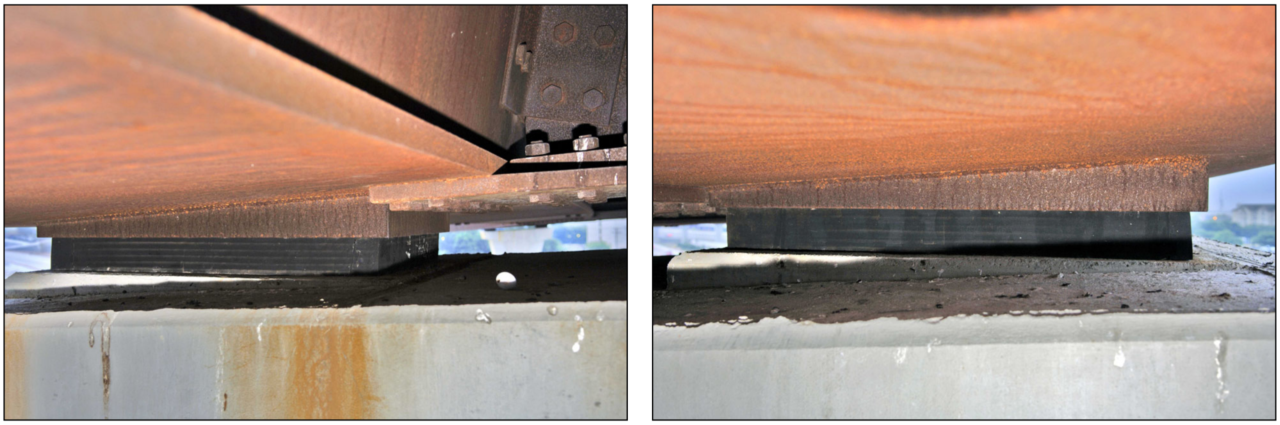
(a) **(b)**



(c) **(d)**

Figure 11. First Interior Bent from East End of the South IH 35 to East US 71 / US 290 Direct Connect Steel Tub Girder Unit, Showing (a) Exterior View of North Bearing, (b) Interior View of North Bearing Showing Damage Caused by Incomplete Sole Plate Coverage, (c) Uplifted Portion of North Bearing, and (d) East Side of Properly Seated South Bearing; Ready for Replacement/Service (09-12-2005).

(a) **(b)**



(c) **(d)**

Figure 12. Second Interior (Fixed) Bent from East End of South IH 35 to East US 71 / US 290 Direct Connect Steel Tub Girder Unit, Showing (a) View Looking Back Toward East End of Unit, (b) Exterior View of North Bearing Showing End Marked "Fixed" (c) West Side of North Bearing, and (d) West Side of South Bearing; Ready for Service (09-12-2005).

(a) (b)

Figure 13. West End of South IH 35 to East US 71 / US 290 Direct Connect Steel Tub Girder Unit, Exterior Views of North Ends of Expansion Bearings; Ready for Service (09-12-2005).

(a) (b)

Figure 14. Two Views of Intermediate Bents of East US 71 / US 290 to North IH 35 Direct Connect Steel Tub Girder Unit; In Service (09-12-2005).

DESIGN PROCEDURE

TxDOT policies and practices for typical elastomeric bearings apply. These are best reflected in the TxDOT Bridge Design Manual, Chapter 9, Section 11, subsection "Design Recommendations", and in TxDOT standard drawing SEB, "Elastomeric Bearing Details, Steel Girders and Beams" (10,11). The following design procedures, employed in the design of the steel tub girder steel laminated elastomeric bearings, of the US 290 / IH 35 interchange in north Austin, include a mixture of AASHTO provisions and TxDOT recommendations:

- Add 0.005 radians to calculated rotations to account for fabrication and placement tolerances. The calculated rotations shall include dead load and live load effects.
- Accommodate 50° F rise and 70° F fall in temperature, assuming annual mean as installation temperature.
- Assume thermal movements are along chords between "free" and "fixed" bents. Draw the chords through the bearings on the outside of curves. Do not provide guides intended to laterally restrain the structure at an expansion joint or other bearing location.
- Use constant thickness pads on level surfaces to avoid introducing horizontal forces
- Use rectangular pads (vs. round pads) because rotation is dominant about the transverse axis.
- Limit maximum horizontal strain to 50% of thickness such that total elastomer thickness will be twice the thermal movement in one direction.
- Limit maximum average stress to 1500 psi, with target dead load stress of 1200 psi. Wave Method B testing requirements.
- Size bearing to prevent slip using conventional 70° F fall and G = 110 to 130 psi. If the resulting height violates stability limits, size pad to accommodate a daily temperature range of 30° F and use a more conservative shear modulus of 175 psi for this check on daily slip since cycling time is shorter and might occur on a very cold day. Reduce the design thickness from "conventional" required value to "daily" required value, based on the allowance that occasional beam–pad interface slip is acceptable. Verify that the elastomer thickness lower limit of 50% of the total thermal movement in one direction is not breeched.
- Use the following shim sizes, as recommended by fabricators:
  - 11 gauge (0.120") for typical bearings
  - 12 gauge (0.105") A<250 in^2 and aspect ration < 1.7
  - 10 gauge (0.135") A>850 in^2 and aspect ration > 1.7
- Use rotational capacity equation from the 15th edition of the AASHTO specifications (see Reference 12) which limits rotation capacity to twice the compressive deformation divided by the bearing dimension perpendicular to the axis of rotation. This provision by itself will not much liberalize rotation capacity, so for the bearing dimension use the length of pad remaining engaged with the supported structure after up to 20% lift-off. The current AASHTO provisions too conservatively restrict pad edge tension and lift-off to zero using stress limits to control rotations rather than providing for explicit calculation of rotation capacity.
- Use minimum pad thickness of L/3, W/3, or D/4 to ensure stability. Conservatively consider only the area of pad engaged after lift-off when determining pad plan dimensions to use in this stability check.
- Use 1" minimum corner thickness sole plates and bevel them to account for girder grade and cross-slope while maintaining level surface for the tub girders to bear on the flat elastomeric bearings.
- Do not vulcanize the pads to the sole plates. Precluding vulcanization will reduce fabrication cost, eliminate induced tension in pad edges, and make the pads softer (vs. vulcanized pads) in shear, providing a slight increase in strain at first slip.

- If dead load stress < 500 psi, recess bearing seat ¼ to contain the pad, thereby mechanically restraining the pads from possibly "walking out".

SUMMARY

In Texas, the steel laminated elastomeric bearing is the bridge design engineers' bearing of choice, because it offers these advantages: it has a superb performance history, it is economical compared with other bearing systems, it provides simplicity of design, fabrication and installation, and it requires minimal maintenance. TxDOT-sponsored research indicates that the AASHTO design provisions seem to be unnecessarily restricting the use of elastomeric bearings. TxDOT engineers have applied the findings of TxDOT and NCHRP sponsored research to extend application of elastomeric bearings to include steel tub girder bridges, which traditionally have required complex mechanically engineered pot or disc bearings. The resulting steel tub girder elastomeric bearing design procedure departs from AASHTO in a number of respects but is a rational extension of the findings of TxDOT-sponsored research performed at UT Austin. TxDOT bridge design engineers and consultants have successfully employed this design procedure in the bearing designs for multiple steel tub girder direct connectors of two major Interstate-to-US highway interchanges constructed and currently under traffic in Austin, Texas. For a more detailed treatment of the design procedure, see Reference 13.

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