Esfarayen Railway Project

Steel-reinforced Elastomeric Bearing Pads Test Report Based on Test Methods: EN-1337-3:2005

AssaFlex

Assamrof Manufacturer of Bridge Components

ww.Assamrof.com

Central office: no 16, 5th floor, Assamrof co, Jolfa commercial complex, East Nazar St., Isfahan

Tel-fax: 03136246011 - 03136285218 -03136266731

Email: info@assamrof.com – technical@assamrof.com

Contents

1-Introduction:

Elastomeric Bearing pads with their crucial rule in mid to long span bridges, should be evaluated to prove their performance in the design parameters of axial load, displacement and rotation and to ensure the safety of their usage in certain mechanical conditions.

Assamrof co, having 8 years of experience in the field of bridge components manufacturing, recently has started to carry out principal tests based on EN-1337-3, one of two mostly used international standards regarding elastomeric bearing pads, to ensure the quality of the products it manufactures and to progress the level of expertise in this field of national industry. Conducting these types of tests under supervision of engineering authorities of the field, not only enhances the quality level which is expected from an Iranian made product, but also can limit the large amount of outflow of currency to buy foreign types of this product, in long-term course.

Three basic types of test on final bearing pad product, and three types of tests on the elastomeric compound by which, bearing pads are manufactured, are conducted before and after production process of bearing pads regarding Esfarayen Railway Project. The tests carried out are almost all that is done as quality control tests in most of foreign well-known manufacturers. By mechanizing, developing the accuracy of tests and minimizing deviations from standard methods, the doors to reach high quality standard elastomeric bearing pads will be open.

2-Shear Modulus Test Based on BSEN-1337-3 (Annex F)

2-1-Concept and Scope of the Test:

The test consists of measuring the shear deflection of a pair of identical elastomeric bearings, when they are subjected to increasing shear loads. From these measurements the apparent shear modulus is calculated and the surfaces of the bearings, when under full load, are examined for defects.

The bearings shall be subjected to shear at a constant and maximum speed of 150 mm / minute to the maximum test deflection vxm (0,7 Tq < vxm <0,9 Tq) and then returned to zero deflection. Where Tq is the average total initial thickness of rubber, including the top and bottom covers when these are not restrained for shearing.

The compressive stress shall be removed and the test pieces left undisturbed for five minutes and then shear again to vxm . Using the values of $\varepsilon_{qx2}, \varepsilon_{qx1}$ ***and*** $\tau_{s2} - \tau_{s1}$ ***which are defined in the formula (1), the shear modulus of each bearing will be calculated. From the other side the sample surfaces shall be free from voids, cracks or faults for example arising from molding or bonding defects.***

In Figure-1 detailed schematics of the test pieces and conditioning of them in test machine is provided and in Figure-2, some pictures taken during the test procedure given.

2-2-Report of Shear Modulus Test Conducted at Assamrof Factory:

Manufacturer: Assamrof co.

Supervised by: Hexa consulting co.

Thickness, number of layers and plan dimensions of test pieces: *As per Appendix-1 - 8(mm)x5(no)+2.5(mm)x2(no) – Total: 45mm –* T_q *:40mm*

Values of shear deflections and shear force (mentioned at table-1):

Size of the cut test piece: main size

Date duration and temperature of test: 21/7/1394 - 30mins - 23℃

Value of compressive load: 101 Ton

Speed of shear strain: 6 cm/mi

Table-1

Parameters/Values	Record #1	Record #2	Record #3	Record #4	Record #5
Horizontal-Jack Pressure (Bar)	37.25	60			
Jack Shear Force $(2*F_x)$ (*Ton*)	5.85	9.42			
Shear Stress (on each bearing)	0.30	0.48			
Displacement (*mm*)	9	19			
Shear Strain (considering Tq=40mm)	0.225	0.475			
Shear Strain (considering Tq=44mm)	0.205	0.432			

Note: Shear stress on each bearing, knowing the measured horizontal-jack force$F_x(Ton)$, is calculated by the following formula*:*

$$\tau = \frac{F_x * 1000 * 9.8}{175 * 175 * 3.14}$$

Calculation of G-Modulus:

$$G_g = \frac{\tau_{s2} - \tau_{s1}}{\varepsilon_{qx2} - \varepsilon_{qx1}} = \frac{0.48 - 0.30}{0.475 - 0.225} = 0.72\ MPa \qquad (1)$$

Note: considering Tq=44mm, design value of elastomer thickness based on Hexa consulting plans, G modulus is calculated as what fallows:

$$G_g = \frac{\tau_{s2} - \tau_{s1}}{\varepsilon_{qx2} - \varepsilon_{qx1}} = \frac{0.48 - 0.30}{0.432 - 0.205} = 0.79\ MPa$$

τ_{s2} is the shear stress and ε_{qx2} the shear strain at a deformation of vx2 = 0,58 Tq, τ_{s1} is the shear stress and ε_{qx1} the shear strain at a deformation of vx1 = 0,27 Tq

Any deviation from the test method:

-The speed of shear strain were above the standard rate and was about 6cm/min

-During the test about 4mm of slip has occurred totally which was deducted from the measured value and then reported.

2-3-Test Requirements EN-1337-3-4.3.1.1:

The value of shear modulus G obtained by test shall comply with the following tolerances:

1-G= 0,9 MPa ± 0,15 MPa, 2-G* = 0,7 MPa ± 0,10 MPa, 3-G* = 1,15 MPa ± 0,20 MPa

****Only if specified by the structure designer.***

The sample surfaces shall be free from voids, cracks or faults for example arising from molding or bonding defects.

2-4-Evaluation of Bearing Pads Based on Requirements:

The value of shear modulus of bearings were calculated to be 0.72 MPa and there was no crack or any other defects visible in the bearing pads. By considering the default value of G modulus to be 0.9 MPa, when no other value is mentioned at the order of the costumer, the measured G modulus is 4% less than 0.75MPa which is the least value that can be considered as 0.9MPa.

G modulus using Tq=44mm, will be equal to 0.79 MPa which is in acceptable range of 0.75Mpa~1.05MPa.

3-Shear bonding Test Based on BSEN-1337-3 (Annex G)

3-1-Concept and Scope of the Test:

This test describes method for testing on the adequacy of the shear bonding strength between the rubber and steel plates in complete elastomeric bearings. The test procedure is the same as that of shear modulus except that the compressive stress is larger and the shear deflection is continued to give larger shear strains (up to a value of 2) and may be carried out on the same test piece as that used for the shear modulus test and may be performed as an extension of Shear Modulus test.

The diagram bellow illustrates the schematics of the testing condition and testing machine. Item " I " stands for the steel platens which supports bearings at the top and bottom. Item " II " is one of bearings which is under shear deformation. Item " III " is the moveable platen to which the shear force is exerted and moves as much as both bearing pads are deflected in shear direction. Item "IV" is high friction surface added to top and bottom and moveable platens to avoid slipping of bearing pads during the test. Another option introduced in the test method to prevent slipping of bearing pads, it is to utilize steel strips restraints to limit movements of bearings in arbitrary direction which is displayed as item " V " in the diagram bellow.

Fz should be calculated to provide a minimum compressive stress of 12 MPa on each bearing.

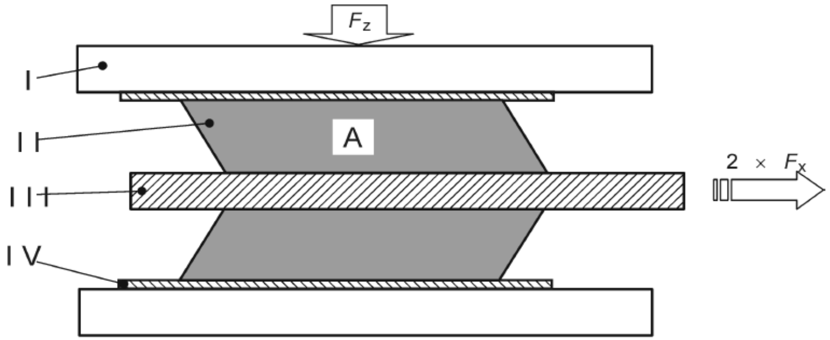


Figure-1-1

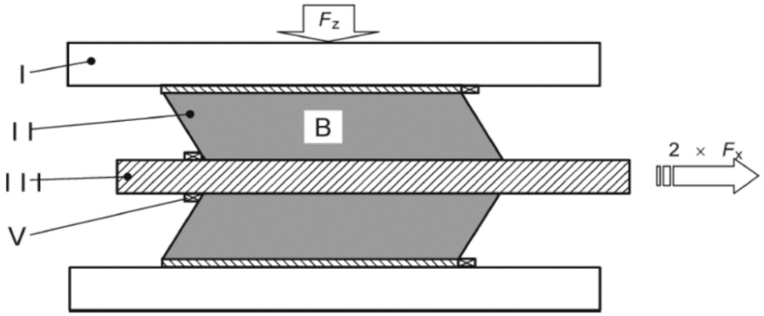


Figure-1-2

3-2-Report of Shear Modulus Test Conducted at Assamrof Factory:

Date, duration and temperature of test: 3/8/1394 - 20mins - 19℃

Name of Manufacturer: Assamrof co.

Value of compressive load (F_z): *1200 KN > 175*175*3.14*12=1139 KN*

Supervised by: *Hexa consulting co.*

Speed of shear strain: *60 mm/s*

Thickness and number of layers and plan dimensions of test pieces: *as per appendix-1 - 8(mm)x5(no)+2.5(mm)x2(no) – Total: 45mm – T_q :40mm*

The size of the cut test piece: *Uncut size*

Values of shear deflections and shear force:

Table-2

Parameters/Values	Record #1	Record #2	Record #3	Record #4	Record #5	Record #6	Record #7	Record #8	Record #9	Record #10
Jack Pressure (Bar)	0	50	100	115	135	140	155	165	175	
Jack Shear Force $(2*F_x)$ (*Ton*)	0	7.85	15.7	18.06	21.20	21.98	24.34	25.91	27.4	
Shear Stress on each bearing (MPa)	0	0.40	0.80	0.92	1.08	1.12	1.24	1.32	1.39	
Displacement (*mm*)	0	8	21	32	41	51	64	76	85	
Shear Strain (Displacement/T_q)	0	0.200	0.525	0.800	1.025	1.275	1.600	1.900	2.125	

Note: In this table the calculation of shear stress is based on the displacement/Tq, where Tq of the manufactured bearings are 4mm less than what has been designed by Hexa consulting co. By considering Tq=44 mm, the design value for Tq, the final shear stress reached at test is been 1.93 which is 3.5% less than what it should be based on the standard EN-1337-3.

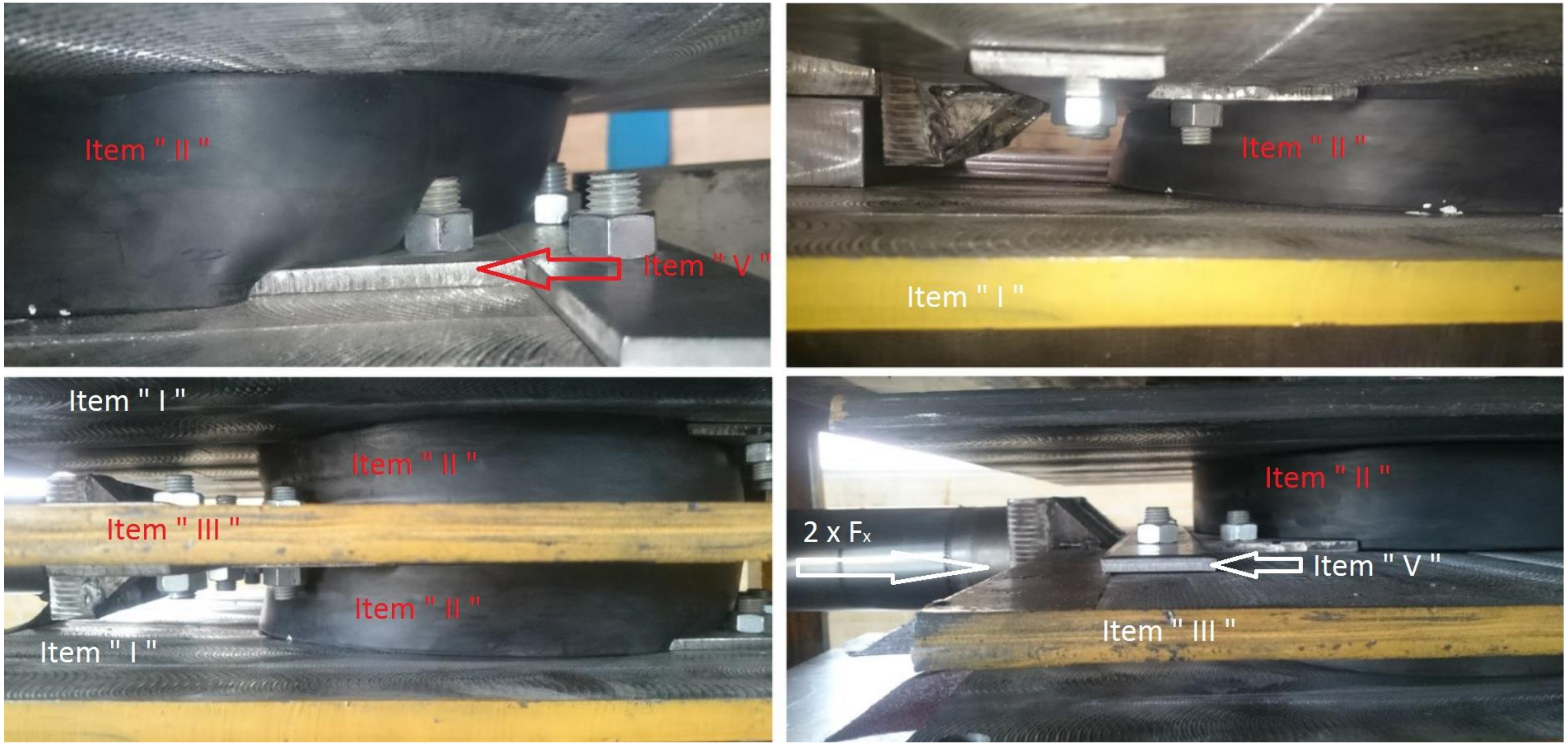

Item " II "
Item " V "
Item " II "
Item " I "
Item " I "
Item " II "
Item " III "
Item " II "
Item " I "
Item " II "
2 x Fx
Item " V "
Item " III "

Figure-2

The following "Shear Force-Displacement" graph has been plotted using measured values and calculating the shear stiffness of bearing having assumed the G modulus of elastomer 0.9 MPa and 1.15 MPa.

$$K_{shear}\left(\frac{N}{mm}\right) = \frac{A(mm^2) * G(MPa)}{T_e(mm)}, \text{assuming } G = 0.7, \quad K_{shear,g=0.7} = \frac{(175)^2 * \pi * 0.7}{4} = 1.684 * 10^3\left(\frac{N}{mm}\right) \quad (2)$$

$$\text{assuming } G = 0.9, \quad K_{shear,g=0.9} = \frac{(175)^2 * \pi * 0.9}{4} = 2.165 * 10^3\left(\frac{N}{mm}\right) \quad (3)$$

$$\text{assuming } G = 1.15, \quad K_{shear,g=1.15} = \frac{(175)^2 * \pi * 1.15}{4} = 2.766 * 10^3\left(\frac{N}{mm}\right) \quad (4)$$

Multiplying vector of measured displacements (Δx) by shear stiffness scalar, we get shear force which should be applied to each bearing pad if it was made out of ideal elastic material with corresponding shear stiffness:

$$\Delta x = [\ 0.0 \quad 8 \quad 21 \quad 32 \quad 41 \quad 51 \quad 64 \quad 76 \quad 85\ ]\ mm$$

$$F_{x,g=0.7}(N) = \Delta x(mm) * K_{shear,g=0.7}\left(\frac{N}{mm}\right) = [\ 0 \quad 13.450 \quad 35.358 \quad 53.878 \quad 69.032 \quad 85.869 \quad 107.757 \quad 127.961 \quad 143.114\ ]\ (KN) \quad (6)$$

$$F_{x,g=0.9}(N) = \Delta x(mm) * K_{shear,g=0.9}\left(\frac{N}{mm}\right) = [\ 0 \quad 17.319 \quad 45.460 \quad 69.272 \quad 88.755 \quad 110.402 \quad 138.544 \quad 164.521 \quad 184.004\ ]\ (KN) \quad (7)$$

$$F_{x,g=1.15}(N) = \Delta x(mm) * K_{shear,g=1.15}\left(\frac{N}{mm}\right) = [\ 0 \quad 22.129 \quad 58.088 \quad 88.514 \quad 113.410 \quad 141.070 \quad 177.029 \quad 210.222 \quad 235.116]\ (KN) \quad (8)$$

$$F_{x,measured}(N) = [\ 0.0 \quad 38.465 \quad 76.930 \quad 88.470 \quad 103.856 \quad 107.702 \quad 119.242 \quad 126.935 \quad 134.628\ ]\ (KN) \quad (9)$$

Graph of shear force displacement:

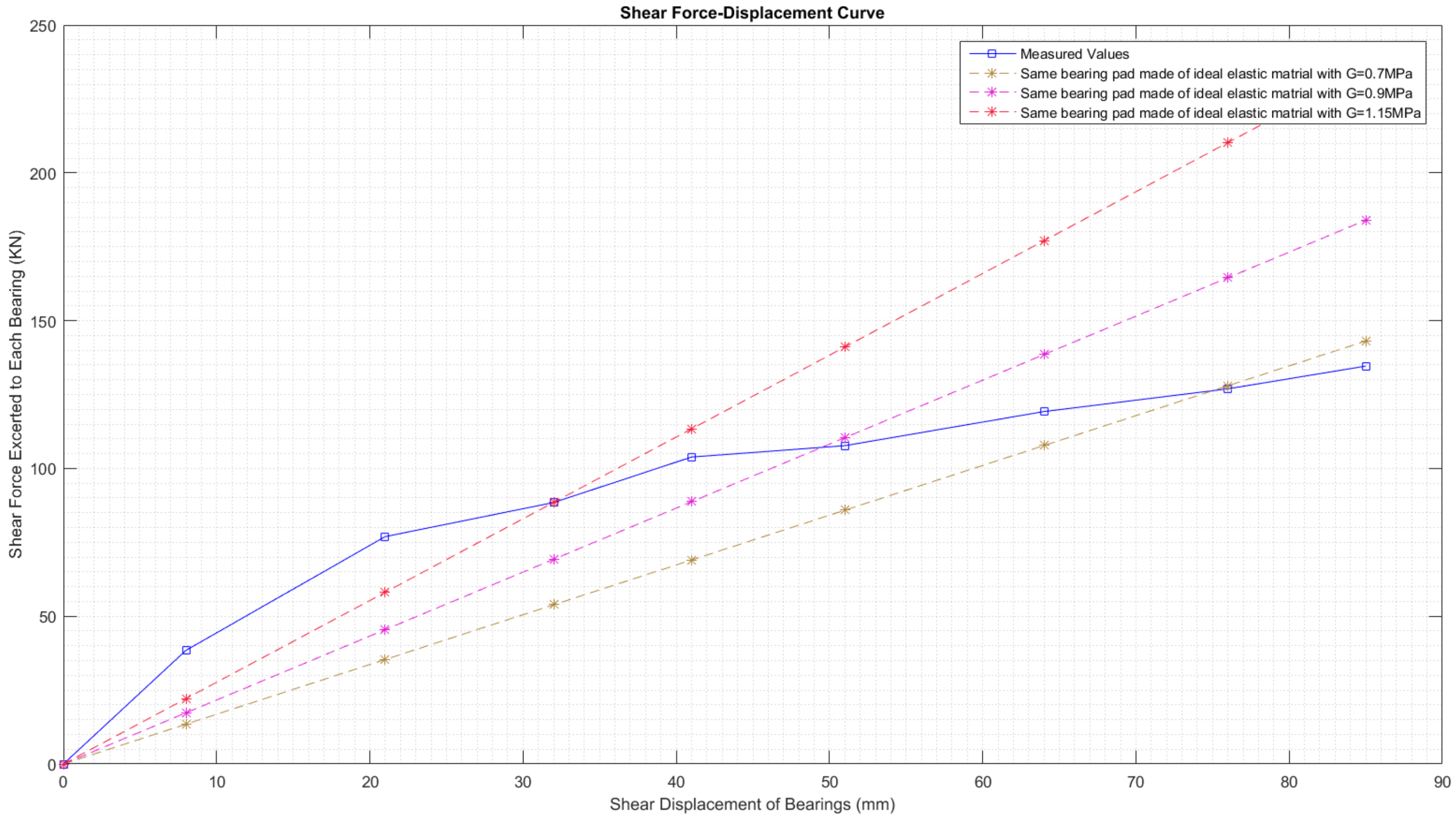


Figure-3

AssaFlex

Manufacturer of Bridge Components

Test Report Based on EN-1337-3:2005-Regarding Esfaryen Railway Project

آسام روف

تولید کننده قطعات پل

Graph of shear strain-stress:

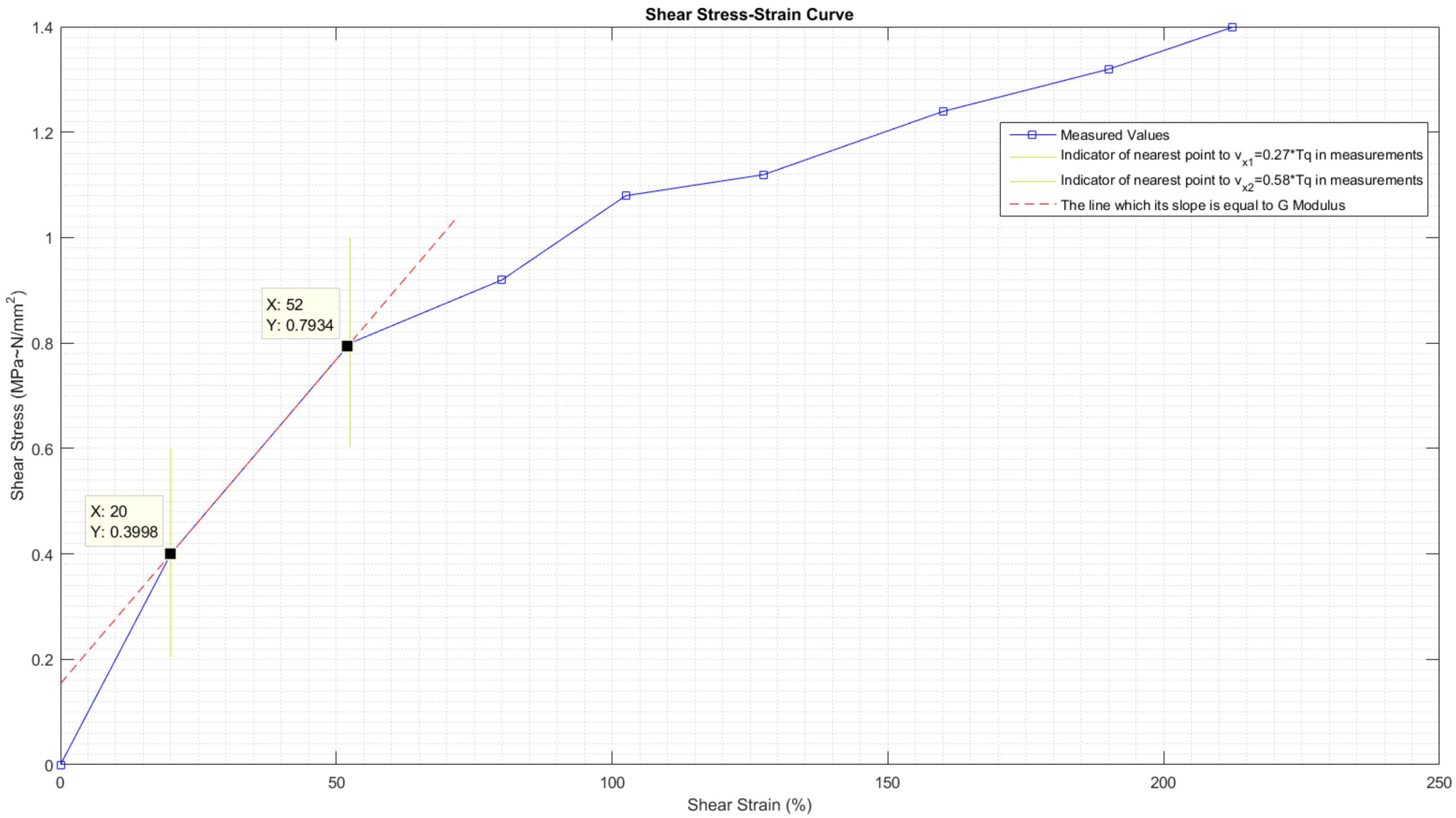


Figure-4

3-3-Test Requirements (EN-1337-3-4.3.2.2):

Based on EN-1337-3:2005-4-3-2-1, the slope of the force-deflection curve shall not show a maximum or a minimum value up to the maximum shear strain of 2. At maximum strain the edge of the bearing shall be free from splitting within the rubber due to molding or bonding defects.

3-4-Evaluation of Bearing Pads Based on Requirements:

After the test, both of bearing pads retrieved their main shapes, no steady bulging or deformation was observed in any of bearing pads. There is no maximum or minimum visible in the force-deflection curves, there was not observed any kind of splitting or bonding defect after reaching shear strain more than 2. There was few defects visible in the elastomer cover of one of two bearings being tested. The defects were of type cracks and not splitting[1].

Value of shear bonding strength: no bonding defect was observed until 1.39 MPa shear stress.

Any deviation from the method: The speed of shear strain jack was higher than the suggested value of the test method.

[1] Splitting should be discriminated from crack referring to their definitions. In the link given bellow one can find the definition for each of the concepts in request:
Split: a split conveys and object being split into smaller pieces or a longer top-to-bottom crack. A split could also be used to describe pieces that are no longer attached at all.
Crack: a line on the surface of something along which it has split without breaking into separate parts. The defining point of a crack is that the cracked object is still together — no matter how tenuous. Often there will not be any visible negative space or hole.
http://english.stackexchange.com/questions/31116/what-are-the-differences-between-crack-slit-crevice-split-and-cleft

4-Level-2 CompressionTest Based on BSEN-1337-3 (Annex H)

4-1-Concept and Scope of the Test:

The test consists of measuring the compression of an elastomeric bearing when subjected to increasing compressive loads. From these measurements the intersecting compression modulus E_{cs} is calculated, and the surface of the bearing, when under full load, is examined for defects.
This test is normally made on bearings by the manufacturer, to check for misplaced reinforcing plates, bond failures at the steel/elastomer interface, surface defects and out of tolerance stiffness under the maximum load for the application. Compression modulus of the bearing can be calculated if during the test we observe the pair of (axial load, vertical deflection) at two points. The standard suggests to do the measurements at (0.33*Fz, corresponding vertical deflection) and (Fz, corresponding vertical deflection).
As the schematic diagram of figure depicts, bearing pads, Item " IV ", being placed at a vertical hydraulic pressure machine ,Item " I ", will be loaded until the axial design load, Fz, calculated based on EN-1337:2005-part5 and beside the visual evaluation of bearing under load, the vertical deflection of bearing under Fz load should be measured using any device with accuracy of less than or higher 2% of maximum measured value. Item " III " in the figure stands for the this vertical deflection measurement device which in our case is a dial indicator. Item " 2 " shows the top and bottom steel plates to support the bearing which is under test.

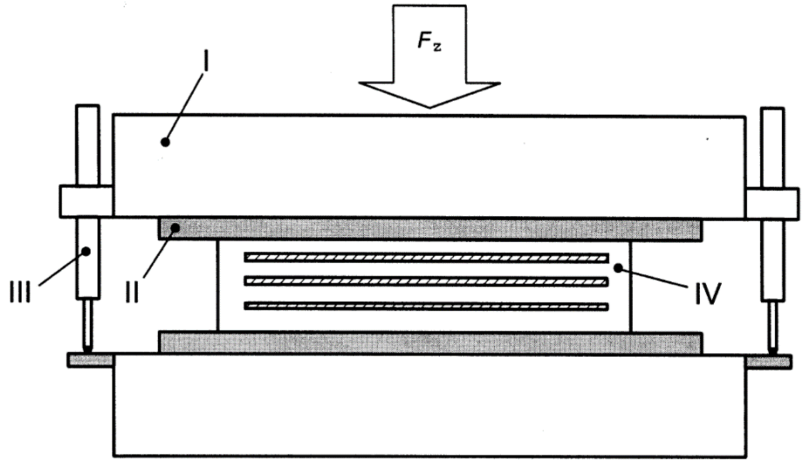


Figure-5

4-2-Report of Compression Test being conducted at factory of Assamrof co:

Name of Manufacturer: Assamrof Co.

Supervised by (Third Party): Hexa Consulting Co.

Thickness and number of layers and plan dimensions of test pieces: As per Attachments

The size of the cut test piece: Main size

Date duration and temperature of test: 21/7/1394 - 20mins - 23℃

Maximum value of compressive load: 141.5 Ton

Speed of compressive strain: ≈100 bar/min

Visual Examination Criteria:

Values of shear deflections and shear force: ***True Placement of Plates:*** ■ ***Standard Bulging:*** ■ ***Standard Bonding:*** ■ ***Venial Cracks:*** ■

Explanation if needed: Three out of six bearings with dimension of $\phi 350 * 69\ (\mathrm{mm})$ where placed under the 141 Ton of vertical load and there was no sign of defect in any. The Hexa consulting representative noticed some outward imperfections on bearings which none of them caused a growing defect during loading test and none of them were among the list of unacceptable outward imperfections in EN-1337-3.

Table-3

Parameters/Values	Record #1 at 1/3 of $F_{z,d}$	Record #2 at $F_{z,d}$	Record #3	Record #4	Record #5	Record #6	Record #7	Record #8	Record #9	Record #10
Press Pressure (Bar)	50	140								
Press Axial Force (*Ton*)	50.5	141.5								
Compressive Stress (MPa)	5.14	14.42								
Vertical Deflection (*mm*)	1.82	6.20								
Vertical Strain	0.045	0.155								

Calculation of Compressive Stiffness:

$$C_c = \frac{F_{z1}-F_{z2}}{v_{z1}-v_{z2}} = \frac{141.5-50.5}{6.20-1.82} = 20.77 \ \text{Ton/mm}$$

- F_{z2} and F_{z1} are respectively the maximum load and 1/3 load of the maximum load
- v_{z2} and v_{z1} are the corresponding vertical deflection of the bearing at the same two loads

Any deviation from the method:

- *The speed of loading were not as per mentioned in the standard passage.*
- *The maximum loading force was not considered based on the bearing design load criteria of EN-1337-3 as the design load can be found in attachments.*

- *Vertical deflection of bearing was not measured exactly at the 1/3 of max load but it was near to it.*

Figure-6

4-3-Test requirements (EN-1337-4.3.3.2):

There shall be no visual evidence of bond failure, misaligned reinforcing plates, or splits in the surface of the elastomer. The corrugations due to the restraining effects of the plates shall be uniform.

4-4-Evaluation of Bearing Pads Based on Test Requirements:

There was no kind of split or crack visible in the bearing pads being tested. No misaligned reinforcing plate and no disordered corrugations in the bearing side covers were observed. The Vertical deflection of bearing pads under 141Ton of Vertical load were measured and it was near to 6mm.

5-Report Summary:

Visual inspections: → ***PASSED***

G-Modulus (part-2 of recent document): ***Measured value =0.72Mpa (Standard range of G-Modulus if G modules of 0.9MPa is required: 0.75~1.05 (MPA))*** →***Nearly Missed***

Bonding Test (Part-3 of recent document): ***No bonding defect or splitting was observed, no local minimum or maximum is occurred in shear stress-strain graph*** → ***PASSED***

Compression Test (Part-4 of recent document): ***No visual defect, compressive stiffness equal to: 20.77 Ton/mm (no standard range is mentioned in the standard)*** → ***PASSED***

Hardness Test : ***62 shore A (60±5 is the range of Hardness in which there is high correlation between hardness and G modulus of 0.9 MPa ,EN-1337-3-Annex-D)*** → ***PASSED***

Stress-Strain Test On Elastomer Sample (Appnedix-3 of recent document): ***Tensile strength= 21.9 MPa, Elongation at Break=534% (Minimum standard value for Tensile strength is 16MPa and minimum standard value for Tensile strength is 425%)*** → ***PASSED***

Appendix-1:

The Properties of the Reinforced Bearing ϕ350x69(40) to be used on the bent caps of Esfarayen Railway Interchange

Based on all design rules provided in EN-1337-3-5 for calculation of geometrical and mechanical properties of steel-reinforced elastomeric bearing pads, the following characteristics are calculated. There may exist differences between what is required by the costumer and the values given bellow but the following values are only indication of values which can be obtained obeying design rules of EN-1337-3-5.

In order to make any customer sure of the performance of the "AssaFlex bearing designer program", a research project granted by Assamrof company is been defined in faculty of civil engineering of ISFAHAN UNIVERSITY to evaluate and correct the performance of that program and as the result the final program is confirmed to conform all the EN-1337-3 design rules by this faculty. The process of registering this program in "Shoraye Aliye Anformatic" is also began.

1-Basic Design Parameters:

ϕ= 350 (mm) (width)

n= 5 (number of internal elastomer layers where the number of internal reinforcement layers is n+1)

$t_{s_i}=4$ (mm) (thickness of internal steel reinforcements)

t_i =8 (mm) (thickness of each internal elastomer layer)

$t_{s_o}=--$ (mm) (thickness of upper and lower steel layers inside bearing and tangent to its surface (bearing plate))

g= 0.9 (N/mm^2) (G modulus or Shear modulus)

μ= 0.3 (friction coefficient)

msf= 1 (Manufacturing Safety Factor) (*msf* *100% of the whole capacity of bearing is considered in calculations)

2-Mechanical Properties of Reinforced Bearing ϕ350*70(40):

$V_{xy,d}$=±24 (mm) (Maximum Vectorial Shear Deflection)

$F_{z,d}$ = 820 (KN) (Maximum Vertical Load in Full Shear Deflection and Rotation)
$F_{z,min}$ = 593 (KN) (Maximum Vertical Load in Full Shear Deflection and Rotation)
$\alpha_{a,d}$ = 0.015 (Rad) (Maximum Rotation along the width in Full Vertical Load and Shear Deflection)
$\sum v_{z,d} = v_c$ =2.1 (mm) (Maximum Vertical Deflection at Max Vertical Load)
R_{xy} = 86 (KN)(Maximum horizontal load exerted by the bearing on the structure to resist translatory movement, *to be considered on structural design*)
$M_d = 4.9 * 10^6$ (N*mm) (Design value of restoring moment due to rotation, *to be considered on structural design*)

General Notes:

- Total Vertical Deflection of a bearing may vary minus or plus 15% of the Estimation which is given above and where this parameter is critical to design of the structure, the stiffness of the bearing should be ascertained by tests.
- The Friction Coefficient in calculations is considered to be 0.3. This value can be varied where the sitting material of the bearings are some material other than steel or concrete.
- Maximum allowable rotation in the above table is calculated to avoid the uplift even in the minimum permitted vertical load.
- AssaFlex Engineering Department will be pleased to tailor Bearings to meet your needs and requirements in a more cost effective manner, if we have knowledge and specifications of your project.

Appendix-2:

The Properties of the Reinforced Bearing ϕ600x70(40) to be used on the bent caps of Esfarayen Railway Interchange

1-Basic Design Parameters:

ϕ= 600 (mm) (width)
n= 5 (number of internal elastomer layers where the number of internal reinforcement layers is n+1)
t_{s_i} = 4 (mm) (thickness of internal steel reinforcements)
t_i =8 (mm) (thickness of each internal elastomer layer)
t_{s_o} = – – (mm) (thickness of upper and lower steel layers inside bearing and tangent to its surface (bearing plate))

g= 0.9 (N/mm^2) (G modulus or Shear modulus)
μ= 0.3 (friction coefficient)
msf=0.7(Manufacturing Safety Factor) (msf *100% of the whole capacity of bearing is considered in calculations)

2-Mechanical Properties of Reinforced Bearing ϕ600*70(40):

$V_{xy,d}$=$\pm$24 (mm) (Maximum Vectorial Shear Deflection)

$F_{z,d}$ = 3700 (KN) (Maximum Vertical Load in Full Shear Deflection and Rotation)

$F_{z,min}$ = 593 (KN) (Maximum Vertical Load in Full Shear Deflection and Rotation)

$\alpha_{a,d}$ = 0.0040 (Rad) (Maximum Rotation along the width in Full Vertical Load and Shear Deflection)

$\sum v_{z,d} = v_c$ =1 (mm) (Maximum Vertical Deflection at Max vertical load)

R_{xy} = 178 (KN)(Maximum horizontal load exerted by the bearing on the structure to resist translatory movement, *to be considered on structural design*)

$M_d = 5.9 * 10^7$ (N*mm) (Design value of restoring moment due to rotation, *to be considered on structural design*)

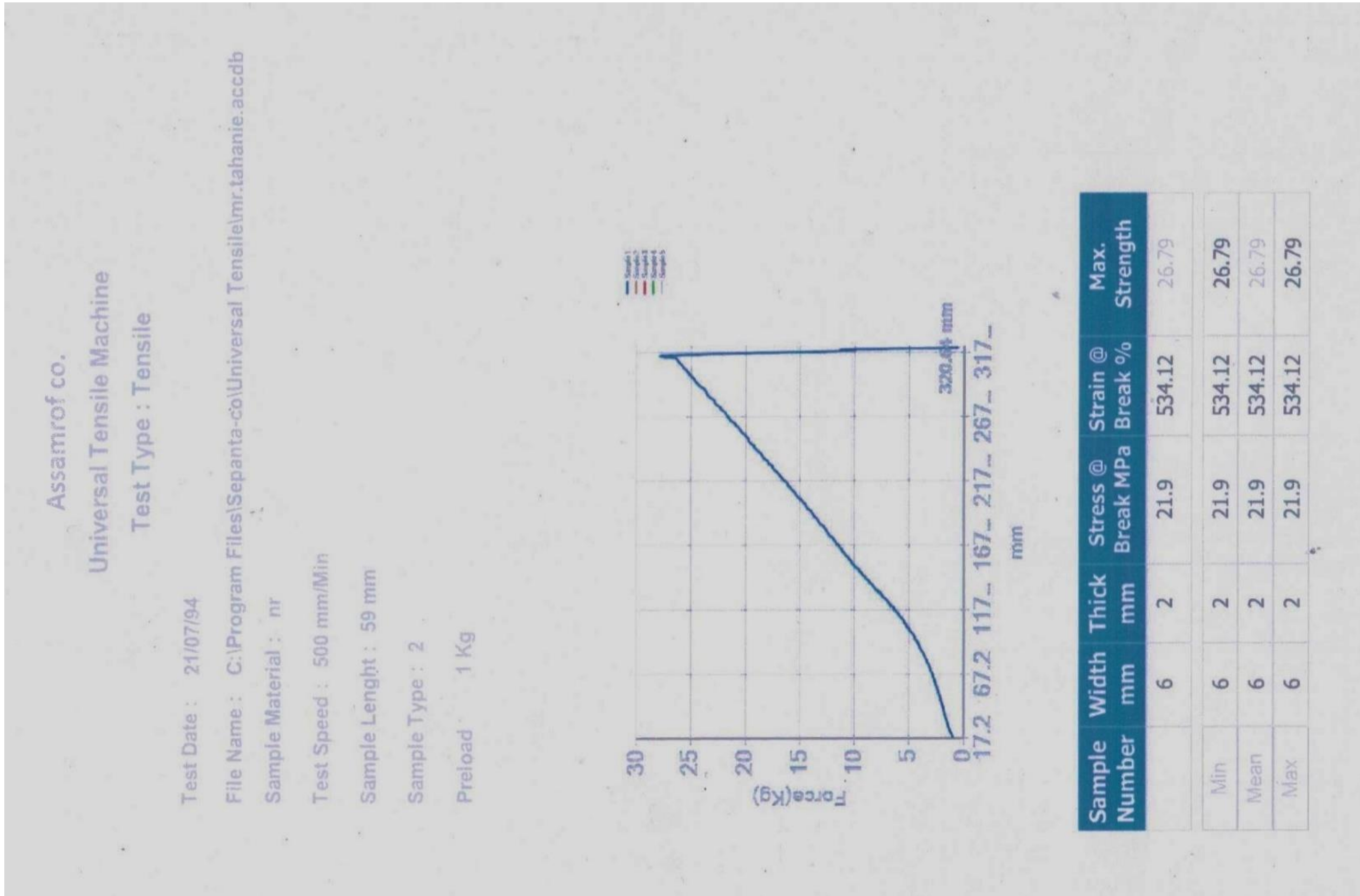
General Notes:

- Total Vertical Deflection of a bearing may vary minus or plus 15% of the Estimation which is given above and where this parameter is critical to design of the structure, the stiffness of the bearing should be ascertained by tests.
- The Friction Coefficient in calculations is considered to be 0.3. This value can be varied where the sitting material of the bearings are some material other than steel or concrete.
- Maximum allowable rotation in the above table is calculated to avoid the uplift even in the minimum permitted vertical load.
- AssaFlex Engineering Department will be pleased to tailor Bearings to meet your needs and requirements in a more cost effective manner, if we have knowledge and specifications of your project.

AssaFlex

Manufacturer of Bridge Components

Appendix-3: Stress-Strain of Elastomer Sample


Assamrof co.

Universal Tensile Machine

Test Type : Tensile

Test Date : 21/07/94

File Name : C:\Program Files\Sepanta-co\Universal Tensile\mr.tahanie.accdb

Sample Material : nr

Test Speed : 500 mm/Min

Sample Lenght : 59 mm

Sample Type : 2

Preload 1 Kg

Sample Number	Width mm	Thick mm	Stress @ Break MPa	Strain @ Break %	Max. Strength
	6	2	21.9	534.12	26.79
Min	6	2	21.9	534.12	26.79
Mean	6	2	21.9	534.12	26.79
Max	6	2	21.9	534.12	26.79

Signed by the manufacturer and third party:

Assamrof Co.

Engineering Office, A. Mostaani