

Rubber Engineering Application for Bridge Construction Sustainability

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OUTLINE

- Introduction of Magdatama
- Rubber Bearings
 - Seismic Isolator – Lead Rubber Bearing
 - R&D – Increasing the lifetime of NR Bearing Pad
- Summary



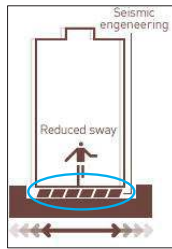
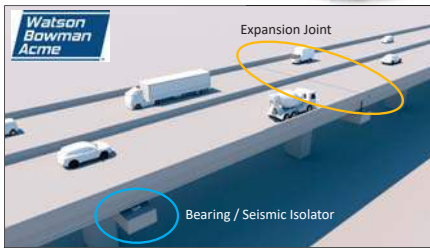
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Specialized Company for Bearing & Expansion Joint Since 1990



- Expansion Joint (EJ):**
- Strip Seal Joint
 - Modular Joint
 - Seismic Modular Joint (Hybrid & X-CEL)



- Structural Bearings:**
- Elastomeric Bearing
 - Pot Bearing
 - Spherical Bearing
 - Lead Rubber Bearing (LRB) – Seismic Isolator



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PLANT 1

Delta Silicon Lippo Industrial Complex (Cikarang), 2015
Area : 5.000 m²



STRIP SEAL JOINT

MODULAR JOINT



X-CEL SEISMIC MODULAR JOINT



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PLANT 2

Karawang International Industrial City, 2021
Area : 11.000 m²



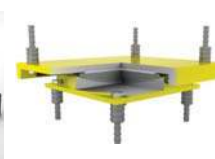
LEAD RUBBER BEARING (LRB)



POT BEARING



Elastomeric Bearing Pad



Spherical Bearing



High Damping Rubber Bearing (HDRB)



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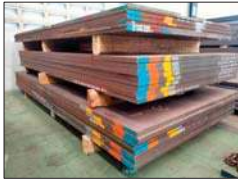
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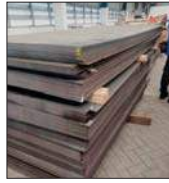
Raw Materials



Natural Rubber
Standard Indonesian Rubber



Steel Plates



Lead Core 99.9%



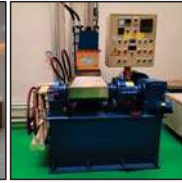
Other components
Raw Materials



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Rubber Testing Laboratory



Complete In-House Rubber Laboratory & Development Facilities, fulfilling EN & AASHTO requirements:

- Universal Tensile Machine
- Aging Oven
- Ozone Chamber
- Rheometer
- Hardness Tester
- Slow Crack Growth set
- Compression Set fixture
- Lab Scale Kneader Mixer
- Lab Scale Open Mill
- Rubber Specimen Grinder
- Specimen Cutter
- etc.



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Bearing Dynamic Testing Machine



Machine Capacity

Vertical : 25.000 kN
Horizontal : 2.700 kN
Dynamic Speed : 1.000 mm/second
Horizontal Stroke : ± 600 mm

Temperature Conditioning

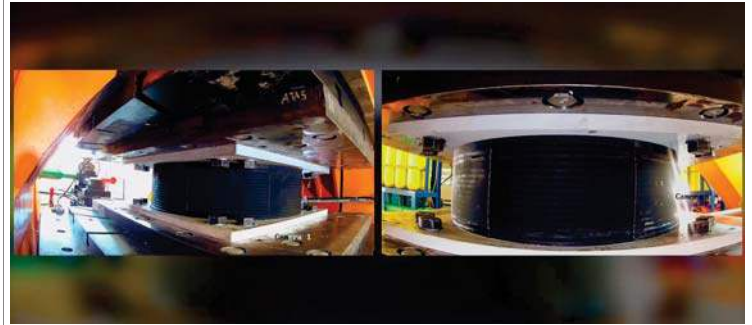
Hot Thermal Chamber : max. 60°C
Cold Thermal Chamber : min. -20°C



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Dynamic Test – Type Testing of LRB



Largest locally produced LRB, Ø1090 mm, Nuls = 21.000 kN



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Testing Documentation – Lead Rubber Bearing (LRB)



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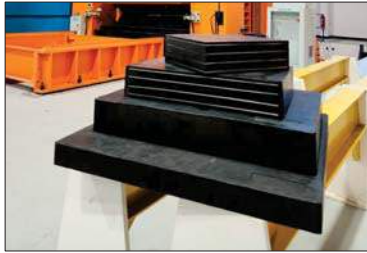
Testing Documentation – Pot Bearing



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Testing Documentation Bearing Pad



TKDN (Local Content):

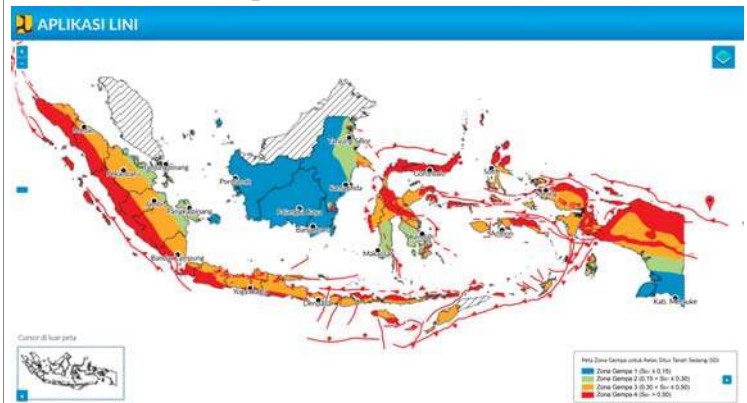
- Lead Rubber Bearing (LRB)
- Seismic Modular Joint
- Pot Bearing
- Strip Seal Joint

TKDN Value - Magda
LRB = 78.75%

OUTLINE

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Seismic Zone Map - Sd

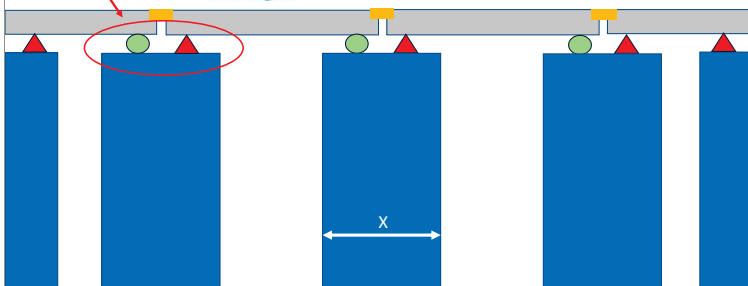


For Sd soil class, most areas are Zone 3 & Zone 4

Reference: <https://lini.binamarga.pu.go.id/>

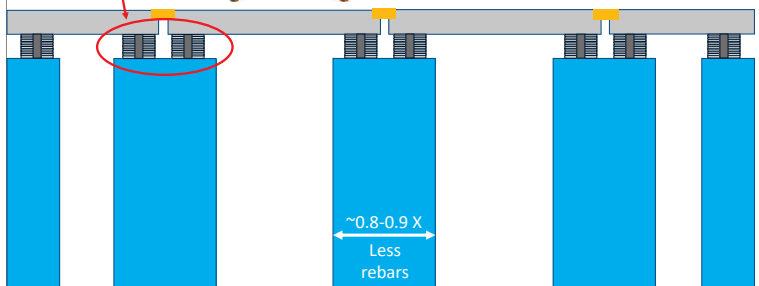
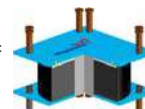
Conventional Bridge in High Seismic Effect Area

Conventional Bearing:
- Pot Bearing, or
- Bearing Pad with dowels



Seismic Isolated Bridge in High Seismic Effect Area

Seismic Base Isolation Bearings:
- Lead Rubber Bearing (LRB)

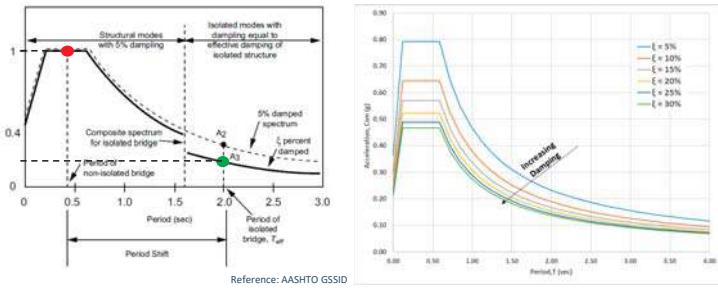


Less Foundations

- Higher Seismic Performance / Integrity of the bridge → expected Fully Operational level after earthquake event → More sustainable bridge
- Less Space → benefit in crowded city area
- May save total cost of construction

Reduction of Seismic Effect

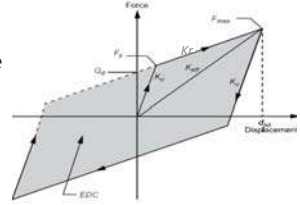
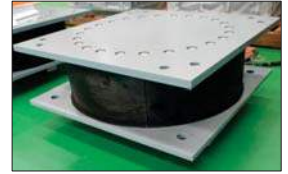
- Ways to reduce seismic effect:
 - Provide lateral flexibility → increase the structure period so the acceleration will be decreased
 - Dissipate seismic energy through *Damping*



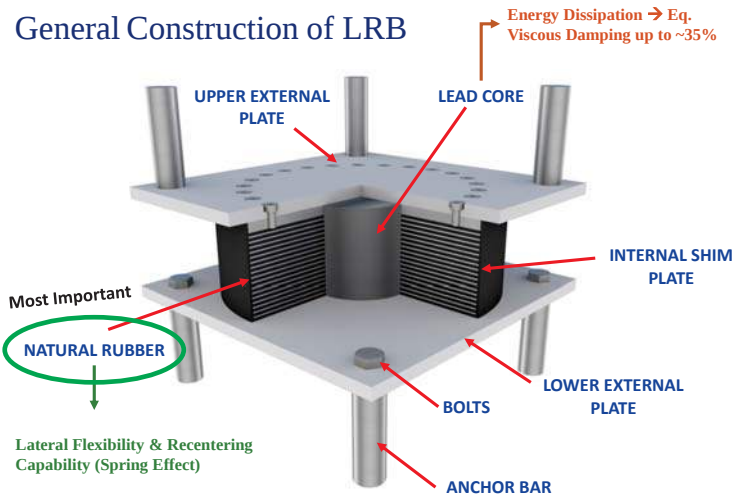
Reference: AASHTO GSSID

Lead Rubber Bearing (LRB)

- LRB → base isolator type used the most for bridges
- Functions:
 - Support Axial (vertical) Load
 - Provide lateral flexibility to increase structure period
 - Dissipate seismic energy through damping → Lead Core
 - Produce restoring force to re-center back the structure → Rubber
- Characteristics of base isolator can be seen from hysteresis loop



General Construction of LRB



Rubber Functions in LRB

- Post Yield Stiffness → Shear modulus
- Characteristics variation caused by temperature, frequency, strain
- Main unifying matrix → Bonding to steel
- Lifetime of LRB → Ageing of Rubber

Long lifetime of Rubber = Long lifetime of LRB, expected at least 60 years

Rubber Specifications

Table 10 — Mechanical and physical properties of low damping elastomers

Property	Requirement	Test Method		
Shear modulus ^a (MPa)	0.3 ≤ G ≤ 0.7	1.1 ≤ G ≤ 1.5		
Tensile strength (MPa), min.				
Moulded test piece	16		ISO 37 Type 2	
Test piece from isolator ^b	14			
Elongation at break (%), min.				
Moulded test piece	450	425	350	
Test piece from isolator ^b	400	375	300	
Tear resistance ^c (kN/m), min.	5	8	10	
Compression set ^d				
70 °C, 24 h, max.	30	30	30	ISO 34 (all parts) & Method A
Ozone resistance ^e				
Elongation 20 % - 96 h	no cracks	no cracks	no cracks	ISO 1431-1
80 °C ± 2 °C				
Accelerated air oven ageing ^f				
Maximum change from unaged value				ISO 180, Method A
Hardness (IRHD)	-5 +0	-5 +0	-5 +0	ISO 40
Tensile strength (%)	115	115	115	ISO 37 Type 2
Elongation at break (%)	125	125	125	

- Rubber Degradation:
- Ozone Attack → Cracks
 - Oxidative Thermal Ageing

Since Natural rubber is prone to ozone attack, enhanced Natural Rubber (NR) Ozone Resistance: 25 ppm → 100 ppm

Rubber Specifications

8.2.2.1.3.5 Shear modulus and damping after accelerated anaerobic ageing

The dynamic shear modulus and damping shall be measured both before ageing and after ageing for 14 days at 70 °C. If moulded test pieces are used, the same one shall be tested un-aged and aged. The ageing shall be carried out in anaerobic conditions and such that volatile compounding ingredients shall not be lost. The shear modulus and damping measurements shall be carried out at a shear strain amplitude of ± 100 %, and the reference frequency (0.5 Hz or the isolation frequency).

The shear modulus and effective damping ratio shall have changed by less than 20 % due to the ageing.

The Design Specification may require that ageing conditions equivalent to a period of 60 years at the average service temperature be estimated for the elastomer compound (using the method outlined in F.1), and that the ageing conditions so estimated be substituted for 14 days at 70 °C. The revised ageing conditions shall not use an ageing temperature above 70 °C.

See informative Annex F. F.1 for guidance on the determination of ageing conditions equivalent to a period of 60 years, and recommendations for achieving anaerobic conditions.

8.2.2.1.4 Shear bond test

8.2.2.1.4.1 Unaged

The shear strength of the steel-elastomer bond shall be checked on unaged test pieces according to the test described in 8.2.4.2.5.3.

The force-displacement curve shall be monotonically increasing, and the test piece shall show no signs of failure or de-bonding. The test report shall conform to 8.2.4.2.5.3.

BS EN 15129:2018
EN 15129:2018 (E)

8.2.2.1.4.2 Aged

The test described in 8.2.2.1.4.1 shall be performed on three test pieces aged 14 days at 70 °C. The ageing shall be carried out in anaerobic conditions and such that volatile compounding ingredients shall not be lost. The Design Specification may require that ageing conditions equivalent to a period of 60 years at the average service temperature be estimated for the elastomer compound (using the method outlined in F.1), and that the ageing conditions so estimated be substituted for 14 days at 70 °C. The revised ageing conditions shall not use an ageing temperature above 70 °C.

The force-displacement curve shall be monotonically increasing, and the test piece shall show no signs of failure or de-bonding. The test report shall conform to 8.2.4.2.5.3.

See informative Annex F. F.1 for guidance on the determination of ageing conditions equivalent to a

Rubber Properties Change, after ageing equal to 60 years condition:

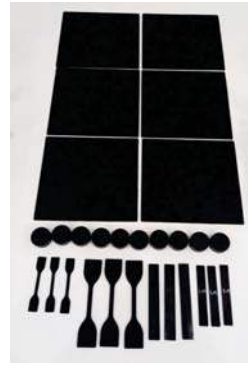
- Shear Modulus < +20%
- Shear Bond – No Failure

Development & Testing Process



Rubber Compound Development

Development & Testing Process



Hardness



Tensile & Elongation



Tear Strength



Ageing, Compression Set



Ozone Test

Test Results Confirmation

TEST REPORT					
MECHANICAL & PHYSICAL PROPERTIES RUBBER					
MSL/PT/17/17/MSL/AN/2023					
Report No	: 042/17/17/17/MSL/AN/2023	Date	: January 31 st , 2023		
Rubber Code	: Natural Rubber - NR50 (S + 0.4)				
Production Date	: January 13 th , 2023				
Batch No	: 13023-08 (R2)				
Sample Received	: January 13 th , 2023				
Date of start test	: January 13 th , 2023				
SUMMARY TEST RESULT					
No	Property	Test Method	Requirement	Result	Conclusion
1	Hardness, Shore A (Plain)	ASTM D2240	-	45	CHECKED
2	Tensile strength (MPa)	ISO 37 type 2	24 min	26.4	PASS
3	Elongation at break (%)	ISO 37 type 2	450 min	834	PASS
4	Tear Resistance (kN/m)	ISO 34 method A	5 min	10.7	PASS
5	Accelerated Air Oxen Aging 70°C x 168h	ISO 188 method A			
	Hardness, Shore A (Plain)	ASTM D2240	-	49	CHECKED
	Hardness change, Shore A (Plain)	ASTM D2240	-5 ~ +8	+4	PASS
	Tensile strength (MPa)	ISO 37 type 2	24 min	25.6	CHECKED
	Tensile strength change (%)	ISO 37 type 2	333	-6.3	PASS
	Elongation at break (%)	ISO 37 type 2	425	385	CHECKED
	Elongation at break change (%)	ISO 37 type 2	625	-7.7	PASS
6	Compression Set 70°C x 24h (%)	ISO 915 type A	30 Cycles	14.8	PASS
7	Shear Resistance (1000 g/cm x 98.1% x 40°C x 30% elongation)	ISO 2433-1	No Cracks	No Cracks	PASS

PUSAT PENELITIAN KARET		LABORATORIUM PENELITIAN	
LABORATORIUM PENUNJANG			
Testing Laboratory			
K. Jendral Sudirman 1, Bogor 16152 (Indonesia) Telp. (081) 8809111 Fax. (081) 8809117 Email: lab@pkn.kan.go.id www.pkn.kan.go.id			
CERTIFICATE OF TESTING			
Sample Number: 07.13.13.23.01.044			
Type of Sample	"Rubber"	Test Method	SR 98 BATCH : 130123-8
Type of Sample Analyzed	"Natural"	Result	
Request Form	PT MAGDATAMA MULTI INDIUSTRI	Hardness (Shore A)	45
Address	Jl. Raya Pura 10, Pura, Kabupaten Indragiri Hilir, Kepulauan Riau, Indonesia	Tensile Strength (MPa)	26.4
Reference Number Date	January 31, 2023	Elongation at break (%)	834
Prepared	February 02, 2023	Change in Hardness, part	+3
Checked	February 02, 2023	Change in Tensile Strength, %	-6.3
Approved	February 02, 2023	Change in Elongation at break, %	-7.7
Properties		Compression set 70°C x 24 hours, %	14.8
		Compression set 70°C x 24 hours, 40°C, 30% elong.	14.8
VALUED FOR TESTED SAMPLE			
By: [Signature]			
Date: 02 March 2023			
By: [Signature]			
Date: 02 March 2023			
DISCLAIMER: Sample number: 07.13.13.23.01.044. The sample test done provided by the Customer			

Shear Modulus Test – EN15129



Rubber Shear Modulus Test Specimens



Dynamic Shear Modulus Test



Anaerobic Ageing Conditioning equal to 60 years condition

Shear Bond Test – EN15129



Shear Bond

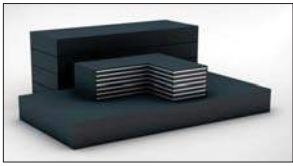


Anaerobic Ageing Conditioning equal to 60 years condition

OUTLINE

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 - Seismic Isolator – Lead Rubber Bearing
 - R&D – Increasing the lifetime of NR Bearing Pad
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Bearing Pads Development



- Most Conventional Bridge Bearing
- Used in less seismic area and for replacement in existing structure

Natural Rubber
abundantly available natural resources in Indonesia

Polychloroprene / Neoprene Rubber (Synthetic)
raw material not produced locally & more expensive

Polychloroprene is seen by many as a superior material



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Rubber Properties Specification – Bearing Pad

PENGUJIAN	STANDAR	KARET ALAM			KARET SINTETIS (NEOPRENE)			SATUAN
		50 Duro	60 Duro	70 Duro	50 Duro	60 Duro	70 Duro	
Persyaratan Utama								
Sifat Fisik	Modulus Geser Minimum *	ASTM D412	0.55 ⁱⁱ			0.55 ⁱⁱ		MPa
	Kekerasan Shore "A"	06-4999	50 ± 5	60 ± 5	70 ± 5	50 ± 5	60 ± 5	70 ± 5
	Kuat Tarik Minimum	06-4966	15.5	15.5	15.5	15.5	15.5	15.5
Perpanjangan Ultimit Minimum *			450 ⁱⁱ	400	300	400 ⁱⁱ	350	300
Persyaratan tambahan								
Ketahanan Terhadap Panas (Heat Resistance)	Temperatur Spesifik Pengujian	06-6315	70	70	70	100	100	100
	Lama Pengusangan (Aging)		168	168	168	70	70	70
	Perubahan Max. Kekerasan "Shore A"		+10	+10	+10	+15	+15	+15
	Perubahan Maksimum pada Kuat Tarik		-25	-25	-25	-15	-15	-15
Perubahan Maksimum pada Perpanjangan Ultimit			-25	-25	-25	-40	-40	-40
			-25	-25	-25	-40	-40	-40
Perubahan akibat tekanan (Compression set)	Temperatur Spesifik Pengujian	06-4889 D365	70	70	70	100	100	100
	Perubahan max. yang diizinkan setelah 22 jam		25	25	25	35	35	35
Kuat Lekat (Adhesion strength)	Kuat lekat minimum pelat yang dijinakan, (lapisan)	06-4892	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)
Ketahanan Ozon	Konsentrasi ozon	06-4894	25	25	25	100	100	100
	Dengan regangan 20 % pada Temperatur ± 37.7°C Prosedur pemampatan D. 518, prosedur A		Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak

SNI 3967:2013 (Adopted AASHTO & EN)



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Test Results

Natural Rubber (NR) compound already with ozone resistant of Chloroprene Rubber (CR)

How about accelerated ageing & compression set? Can NR perform as well as CR?



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Rubber Properties Specification – NR = CR ?

PENGUJIAN	STANDAR	KARET ALAM			KARET SINTETIS (NEOPRENE)			SATUAN
		50 Duro	60 Duro	70 Duro	50 Duro	60 Duro	70 Duro	
Persyaratan Utama								
Sifat Fisik	Modulus Geser Minimum *	ASTM D412	0.55 ⁱⁱ			0.55 ⁱⁱ		MPa
	Kekerasan Shore "A"	06-4999	50 ± 5	60 ± 5	70 ± 5	50 ± 5	60 ± 5	70 ± 5
	Kuat Tarik Minimum	06-4966	15.5	15.5	15.5	15.5	15.5	15.5
Perpanjangan Ultimit Minimum *			450 ⁱⁱ	400	300	400 ⁱⁱ	350	300
Persyaratan tambahan								
Ketahanan Terhadap Panas (Heat Resistance)	Temperatur Spesifik Pengujian	06-6315	70	70	70	100	100	100
	Lama Pengusangan (Aging)		168	168	168	70	70	70
	Perubahan Max. Kekerasan "Shore A"		+10	+10	+10	+15	+15	+15
	Perubahan Maksimum pada Kuat Tarik		-25	-25	-25	-15	-15	-15
Perubahan Maksimum pada Perpanjangan Ultimit			-25	-25	-25	-40	-40	-40
			-25	-25	-25	-40	-40	-40
Perubahan akibat tekanan (Compression set)	Temperatur Spesifik Pengujian	06-4889 D365	70	70	70	100	100	100
	Perubahan max. yang diizinkan setelah 22 jam		25	25	25	35	35	35
Kuat Lekat (Adhesion strength)	Kuat lekat minimum pelat yang dijinakan, (lapisan)	06-4892	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)	8.9 (5.2)
Ketahanan Ozon	Konsentrasi ozon	06-4894	25	25	25	100	100	100
	Dengan regangan 20 % pada Temperatur ± 37.7°C Prosedur pemampatan D. 518, prosedur A		Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak

SNI 3967:2013 (AASHTO – EN)



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Development & Testing Process



Dozens of natural rubber compound trial



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Test Results

Accelerated ageing & compression set? Can NR perform as well as CR? **YES, right compound NR = CR**

So, NR can replaces the needs of CR for bearing pad



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Summary

- Rubber engineering contributes to the sustainability of bridge construction through the usage of rubber bearings (LRB or Bearing Pad)
- Increasing the lifetime of the rubber bearings can be done by increasing the resistance of the natural rubber against degradation
- Natural Rubber (NR) can be equally as good as Polychloroprene / Neoprene (CR) rubber, with the right compounding

THANK YOU

