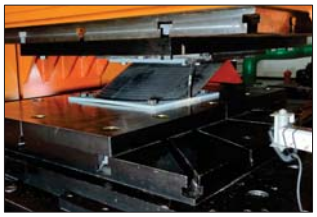
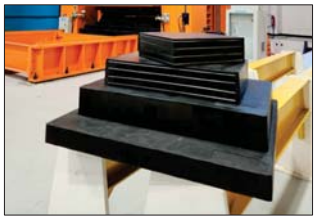
Rubber Engineering Application for Bridge Construction Sustainability





10th REAAA Business Forum – Knowledge Sharing

Friday, 25th August 2023

By

Felix Hotama, B.Sc., MM.

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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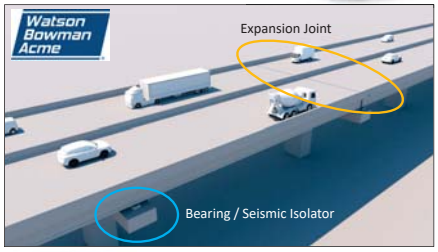
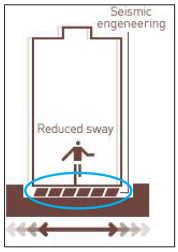
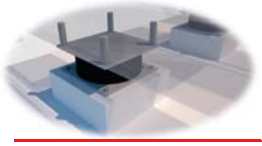
Specialized Company for Bearing & Expansion Joint Since 1990

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

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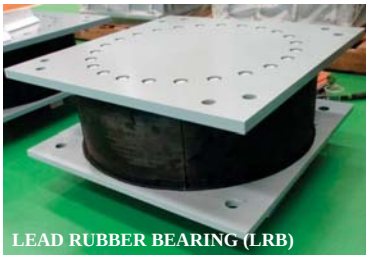

Elastomeric Bearing Pad

Spherical Bearing

High Damping Rubber Bearing (HDRB)

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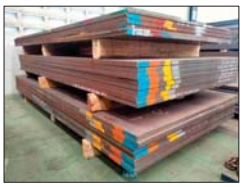
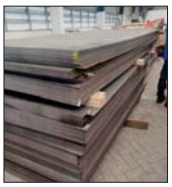
Raw Materials

Natural Rubber
Standard Indonesian Rubber





Steel Plates

Lead Core 99.9%

Other components
Raw Materials

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.

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

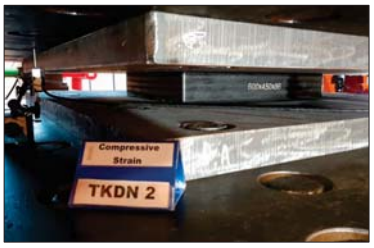
Dynamic Test – Type Testing of LRB

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

Testing Documentation – Lead Rubber Bearing (LRB)

Testing Documentation – Pot Bearing

Testing Documentation Bearing Pad




Kementerian Perindustrian
REPUBLIK INDONESIA

TANDA SAH CAPAIAN TINGKAT KOMPONEN DALAM NEGERI

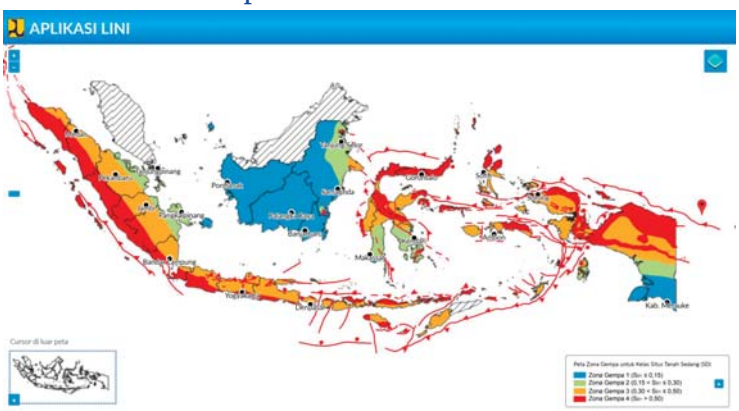
TKDN (Local Content):
- Lead Rubber Bearing (LRB)
- Seismic Modular Joint
- Pot Bearing
- Strip Seal Joint

TKDN Value - Magda LRB = **78.75%**

OUTLINE

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

Seismic Zone Map - Sd

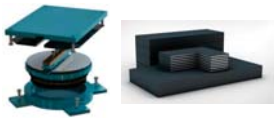


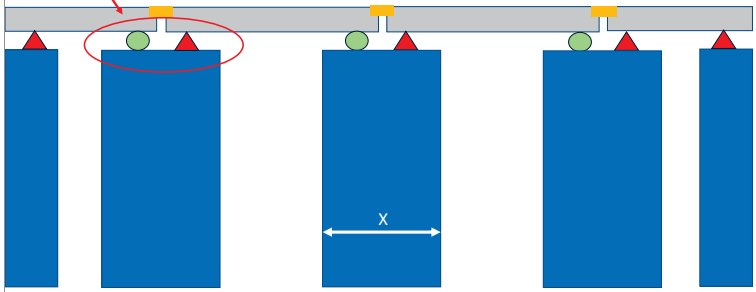
For Sd soil class, most areas are Zone 3 & Zone 4

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

Conventional Bridge in High Seismic Effect Area

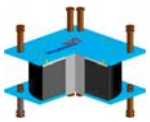
Conventional Bearing:
- Pot Bearing, or
- Bearing Pad with dowels



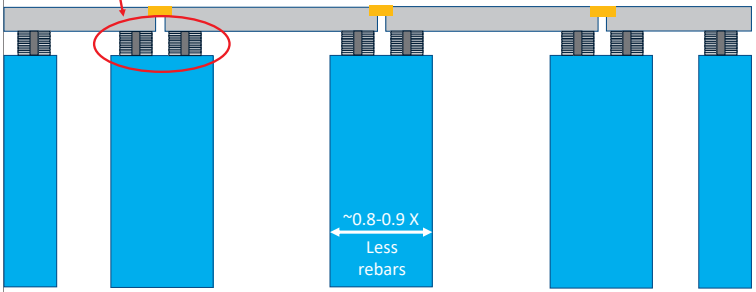


Seismic Isolated Bridge in High Seismic Effect Area

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



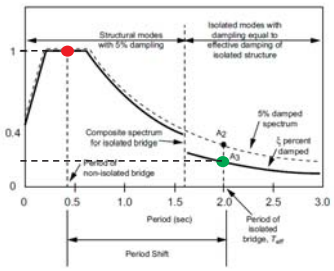
- Higher Seismic Performance / Integrity of the bridge → expected Fully Operational level after earthquake event → More sustainable bridge
- Less Space → benefit in crowded city area
- May save total cost of construction

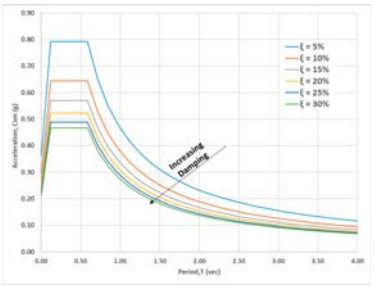


Less Foundations

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*

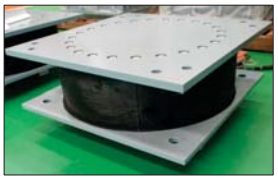


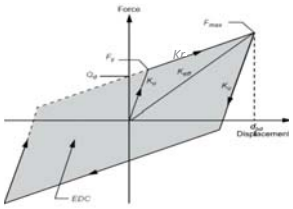


Reference: AASHTO GSSID

Lead Rubber Bearing (LRB)

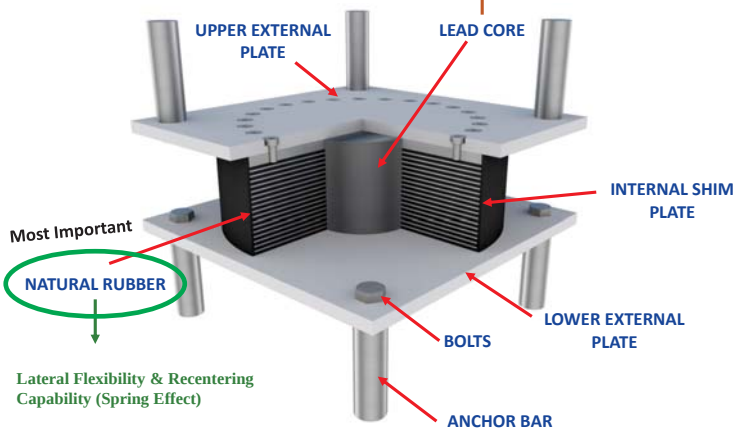
- LRB → base isolator type used the most for bridges
- Functions:
  - Support Axial (vertical) Load
  - Provide lateral flexibility to increase structure period
  - Dissipate seismic energy through damping → Lead Core
  - Produce restoring force to re-center back the structure → Rubber
- Characteristics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





General Construction of LRB

Energy Dissipation → Eq. Viscous Damping up to ~35%



Lateral Flexibility & Recentering Capability (Spring Effect)

Rubber Functions in LRB

1. Post Yield Stiffness → Shear modulus
2. Characteristics variation caused by temperature, frequency, strain
3. Main unifying matrix → Bonding to steel
4. 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	0,7 < G ≤ 1,1	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	ISO 34 (all parts) & Method A
Compression set [d]				ISO 815 (all parts)
70 °C, 24 h, max.	30	30	30	Type A
				25 % compression
Ozone resistance [e]				
Elongation 30 % - 96 h				
40 °C ± 2 °C	no cracks	no cracks	no cracks	ISO 1431-1
Accelerated air oven ageing [f]				ISO 188,
Maximum change from unaged value				Method A
Hardness (IRHD)	-5, +8	-5, +8	-5, +8	ISO 48
Tensile strength (%)	±15	±15	±15	ISO 37 Type2
Elongation at break (%)	±25	±25	±25	-

Because the ozone and ageing tests are checks that appropriate antidegradants have been included, not tests related to service performance, their effectiveness necessitates that the conditions should be appropriate to the elastomer used in manufacture of the devices.

[e] The ozone concentration shall be appropriate to the elastomer used. For example, for natural rubber based vulcanisates, 25 pphm shall be used and for polychloroprene based vulcanisates 100 pphm. For elastomers with no unsaturated carbon-carbon bonds, an ozone test need not be performed.

Rubber Degradation:
1. Ozone Attack → Cracks
2. Oxidative Thermal Ageing

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

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

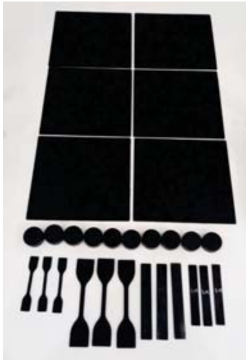
Rubber Properties Change, after ageing equal to 60 years condition:
1. Shear Modulus < +20%
2. Shear Bond – No Failure

Development & Testing Process

Rubber Compound Development

MSLAB Magdatama

Development & Testing Process



Hardness

Tensile & Elongation

Tear Strength

Ageing, Compression Set

Ozone Test

MSLAB Magdatama

Test Results Confirmation

MSLAB **TEST REPORT** Magdatama

MECHANICAL & PHYSICAL PROPERTIES RUBBER

Report No : 041/TSRT/CT/mSLAB/I/2023 Date : January 31st, 2023

Rubber Code : Natural Rubber - NR56 (G = 0,4)

Production Date : January 13th, 2023

Batch No : 130123-08 (822)

Sample Received : January 13th, 2023

Date of start test : January 13th, 2023

SUMMARY TEST RESULT

No	Property	Test Method	Requirement	Result	Conclusion
1	Hardness, Shore A (Point)	ASTM D2240	-	45	CHECKED
2	Tensile strength (MPa), Moulded test piece	ISO 37 type 2	16 min	26.4	PASS
3	Elongation at break (%), Moulded test piece	ISO 37 type 2	450 min	634	PASS
4	Tear Resistance (kN/m)	ISO 34 method A	5 min	10.7	PASS
5	Accelerated Air Oven Aging 70°C x 168h	ISO 188 method A			
	Hardness, Shore A (Point)	ASTM D2240	-	49	CHECKED
	Hardness change, Shore A (Point)	ASTM D2240	-5 ~ +8	+4	PASS
	Tensile strength (MPa), Moulded test piece	ISO 37 type 2	-	25.0	CHECKED
	Tensile Strength change (%)	ISO 37 type 2	±15	-5.3	PASS
	Elongation at break (%), Moulded test piece	ISO 37 type 2	-	585	CHECKED
	Elongation at break change (%)	ISO 37 type 2	±25	-7.7	PASS
6	Compression Set 70°C x 24h (%)	ISO 815 type A 25% Compression	30 max	14.8	PASS
7	Ozon Resistance (100 pphm x 96 h x 40°C x 30% elongation)	ISO 1431-1	No Cracks	No Cracks	PASS

PUSAT PENELITIAN KARET

Indonesian Rubber Research Institute

LABORATORIUM PENGUJI

Testing Laboratory

KAN

CERTIFICATE OF TESTING

Sample Number MT.LU.01.23.01.044

Request from : PT MAGDATAMA MULTI INDUSTRI

Received : January 31, 2023

Finished : February 28, 2023

Properties	Test Method	Result NR 56 BATCH : 130123-8
Hardness, Shore A	ISO 48-4:2018	46
Tensile Strength (dumbbell), MPa	SNI ISO 37:2018	25.8
Elongation at break, %	SNI ISO 37:2018	600
After aging at 70°C, 168 hours (ISO 188:2011)		
• Change in Hardness, point	ISO 48-4:2018	+ 3
• Change in Tensile Strength, %	SNI ISO 37:2018	[illegible]
• Change in Elongation at break, %	SNI ISO 37:2018	[illegible]
Tear strength, kN/m	[illegible]	[illegible]
Compression set 25%, 70°C, 24 hours, %	ISO 815:2014	[illegible]
Ozone resistance 100 pphm, 30% strain, 40°C, 96 hours	ISO 1431-1:2012	No Cracks

VALID FOR TESTED SAMPLE

NOT BE COPIED

DISCLAIMER:
The Sample has been provided by the Customer

Bogor, 03 March 2023

MSLAB Magdatama

Shear Modulus Test – EN15129

Rubber Shear Modulus
Test Specimens

Dynamic Shear
Modulus Test

Anaerobic Ageing Conditioning
equal to 60 years condition

MSLAB Magdatama

Shear Bond Test – EN15129

Shear Bond

Anaerobic Ageing Conditioning
equal to 60 years condition

MSLAB Magdatama

OUTLINE

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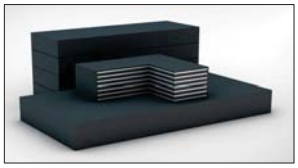
- ➢ **Rubber Bearings**
  - Seismic Isolator – Lead Rubber Bearing
  - **R&D – Increasing the lifetime of NR Bearing Pad**
- Summary

MSLAB Magdatama

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

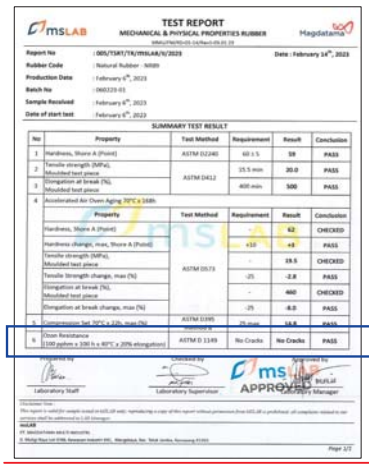
Polychloroprene is seen by many as a superior material

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 a)			0,55 a)		MPa
	Kekerasan Shore "A"	06-4999	50 ± 5	60 ± 5	70 ± 5	50 ± 5	60 ± 5	70 ± 5	Point
	Kuat Tarik Minimum	06-4966	15,5	15,5	15,5	15,5	15,5	15,5	MPa
	Perpanjangan Ultimit Minimum *		450 a)	400	300	400 a)	350	300	%
Persyaratan tambahan									
Ketahanan Terhadap Panas (Heat Resistance)	Temperatur Spesifik Pengujian	06-6315	70	70	70	100	100	100	°C
	Lama Pengusangan (Aging)		168	168	168	70	70	70	Jam
	Perubahan Max. Kekerasan "Shore A"		+ 10	+ 10	+ 10	+ 15	+ 15	+ 15	Point
	Perubahan Maksimum pada Kuat Tarik		-25	-25	-25	-15	-15	-15	%
	Perubahan Maksimum pada Perpanjangan Ultimit		-25	-25	-25	-40	-40	-40	%
Perubahan akibat tekanan (Compression set)	Temperatur Spesifik Pengujian	06-4889 D395	70	70	70	100	100	100	°C
	Perubahan max. yang dizinkan setelah 22 jam		25	25	25	35	35	35	%
Kuat Lekat (Adhesion strength)	Kuat lekat minimum lapisan pelat yang diijinkan, (lapisan fabric)	06-4892	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	kN/m
Ketahanan Ozon	Konsentrasi ozon	06-4894	25	25	25	100	100	100	pphm
	Lama pengujian		48	48	48	100	100	100	Jam
	Dengan regangan 20 % pada Temperatur ± 37,7°C Prosedur penempatan D, 518, prosedur A		Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	

SNI 3967:2013 (Adopted AASHTO & EN)

Test Results


TEST REPORT
MECHANICAL & PHYSICAL PROPERTIES RUBBER

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?

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 a)			0,55 a)		MPa
	Kekerasan Shore "A"	06-4999	50 ± 5	60 ± 5	70 ± 5	50 ± 5	60 ± 5	70 ± 5	Point
	Kuat Tarik Minimum	06-4966	15,5	15,5	15,5	15,5	15,5	15,5	MPa
	Perpanjangan Ultimit Minimum *		450 a)	400	300	400 a)	350	300	%
Persyaratan tambahan									
Ketahanan Terhadap Panas (Heat Resistance)	Temperatur Spesifik Pengujian	06-6315	70	70	70	100	100	100	°C
	Lama Pengusangan (Aging)		168	168	168	70	70	70	Jam
	Perubahan Max. Kekerasan "Shore A"		+ 10	+ 10	+ 10	+ 15	+ 15	+ 15	Point
	Perubahan Maksimum pada Kuat Tarik		-25	-25	-25	-15	-15	-15	%
	Perubahan Maksimum pada Perpanjangan Ultimit		-25	-25	-25	-40	-40	-40	%
Perubahan akibat tekanan (Compression set)	Temperatur Spesifik Pengujian	06-4889 D395	70	70	70	100	100	100	°C
	Perubahan max. yang dizinkan setelah 22 jam		25	25	25	35	35	35	%
Kuat Lekat (Adhesion strength)	Kuat lekat minimum lapisan pelat yang diijinkan, (lapisan fabric)	06-4892	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	6,9 (5,2)	kN/m
Ketahanan Ozon	Konsentrasi ozon	06-4894	25	25	25	100	100	100	pphm
	Lama pengujian		48	48	48	100	100	100	Jam
	Dengan regangan 20 % pada Temperatur ± 37,7°C Prosedur penempatan D, 518, prosedur A		Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	Tanpa Retak	

SNI 3967:2013 (AASHTO – EN)

Development & Testing Process

Dozens of natural rubber compound trial

Test Results


TEST REPORT
MECHANICAL & PHYSICAL PROPERTIES RUBBER

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

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

OUTLINE

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

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

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