15th December 2011

Railway Technical Research Institute (RTRI)

- High Speed Shinkansen- Bolsterless Bogie, Improving Running Performance and Riding Confort
- Noise Problem of High-speed Train in Japan : Development of Noise Reduction Technology
- Recent Technologies of Train Control Systems in Japan
- Track Technology for High Speed Line in Japanese Railways

High Speed Shinkansen

Bolsterless Bogie
Improving Running Performance and Riding Comfort

Okamoto Isao

Technical Adviser
Railway Technical Research Institute, Japan

Shinkansen Trains

History of maximum speed of Shinkansen

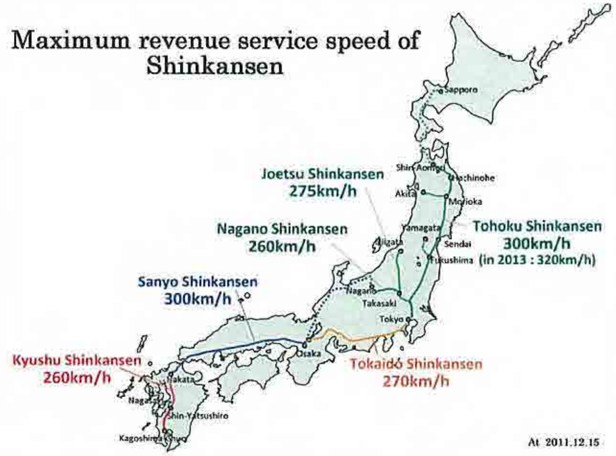
(1) Maximum revenue service speed

･1964～	210km/h	inauguration of Tokaido Shinkansen Series 0 "Hikari"	
･1986～	220km/h	Series 0, 100	Tokaido Shinkansen
･1985～	240km/h	Series 200	Tohoku Shinkansen
(1987	breakup and privatization of Japanese National Railways)		
･1992～	270km/h	Series 300 "Nozomi"	Tokaido Shinkansen
･1997～	300km/h	Series 500 "Nozomi"	Sanyo Shinkansen
･2011～	300km/h	Series E5 "Hayabusa"	Tohoku Shinkansen
(･2013～	320km/h		Tohoku Shinkansen)

(2) Maximum test speed

･1996	443km/h	Series 300X	Tokaido Shinkansen

Maximum revenue service speed of Shinkansen



Development of High-Speed Shinkansen Bogies

Conventional Shinkansen Bogie (1964～1992 Series 0, 100, 200)

Bolsterless Shinkansen Bogie (1992～ Series 300 and later)

	Conventional Shinkansen Bogie for Series 100	Bolsterless Shinkansen Bogie for Series 700
Bogie weight	9,860 kg	6,660 kg
Unsprung mass	4,630 kg	3,420 kg

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Design Concept for Bolsterless Shinkansen Bogie

(1)To attain a good balance between increased high-speed running stability and improved performance in negotiating curves to reduce lateral force,

①Select optimum lateral and longitudinal stiffness of the axle box suspension between wheelset and bogie frame by newly developed analytical method.

② Lighten a bogie weight, especially unsprung mass by adopting,

- Simplified shape (Bolsterless, End-beamless) bogie frame made of high-strength steel sheet 8 mm thick
- Aluminum alloy gear-case and axle-box
- Hollow axle and 860 mm diameter wheel
- Caliper-type brake gear and monobloc brake disc
- Asynchronous induction motor

(2)To improve riding comfot, adopt newly designed primary and secondary suspension

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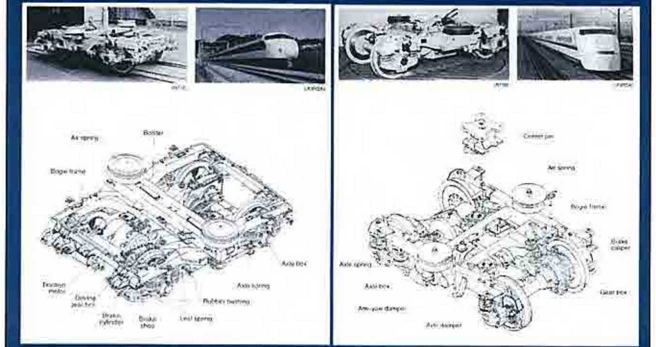
Comparison Conventional and Bolsterless Bogie

(Conventional Shinkansen Bogie) (Bolsterless Shinkansen Bogie)



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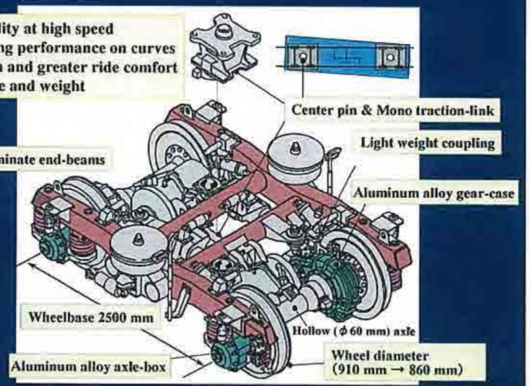
Bolsterless Shinkansen Bogie

- Greater stability at high speed
- Higher running performance on curves
- Less vibration and greater ride comfort
- Smaller in size and weight



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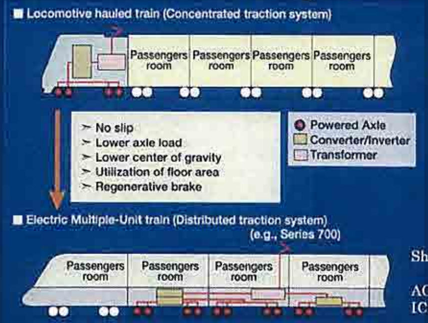
Comparison Concentrated & Distributed traction system



TGV (France)
ICE (Germany)

Shinkansen (Japan)

AGV (France)
ICE3 (Germany)

By distributing traction devices, EMU attained high-speed, lightweight, environmental friendliness, etc.

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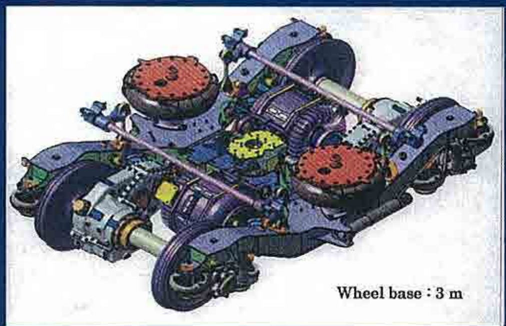
AGV Bogie (Alsthom France)



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ICE3 Bogie (Siemens Germany)

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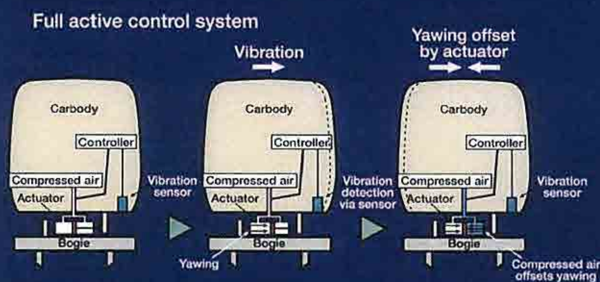
Full active control system improving riding comfort



for Series 500, E2, E3, E5, E6

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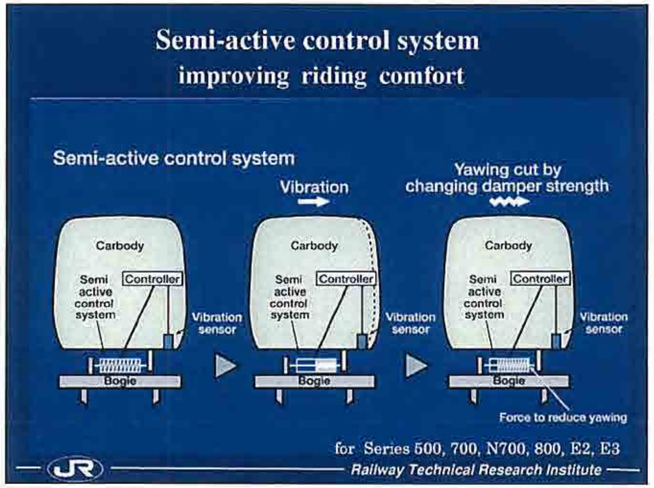
Semi-active control system
improving riding comfort
Semi-active control system
Vibration
Yawing cut by changing damper strength
Carbody
Semi active control system
Controller
Vibration sensor
Bogie
Force to reduce yawing
for Series 500, 700, N700, 800, E2, E3
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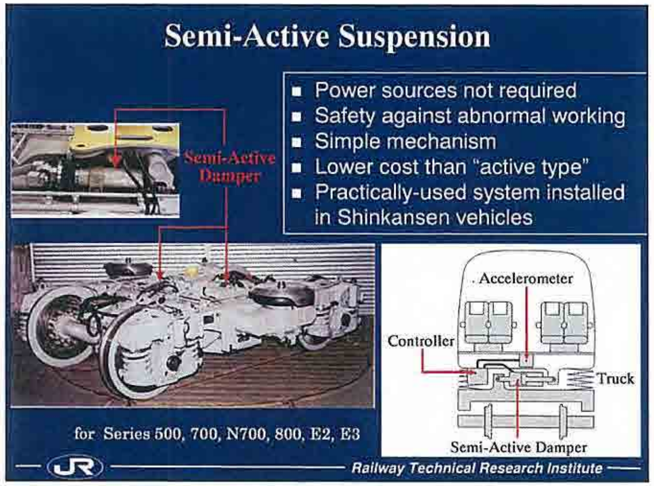
Semi-Active Suspension
Power sources not required
Safety against abnormal working
Simple mechanism
Lower cost than "active type"
Practically-used system installed in Shinkansen vehicles
Semi-Active Damper
Accelerometer
Controller
Truck
Semi-Active Damper
for Series 500, 700, N700, 800, E2, E3
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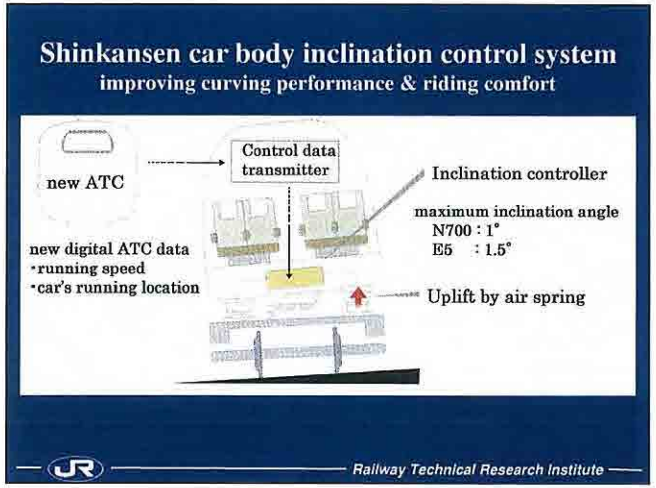
Shinkansen car body inclination control system
improving curving performance & riding comfort
new ATC
Control data transmitter
Inclination controller
maximum inclination angle
N700 : 1°
E5 : 1.5°
new digital ATC data
・running speed
・car's running location
Uplift by air spring
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High-Speed Rolling Stock Test Plant
Maximum test speed : 500 km h-1
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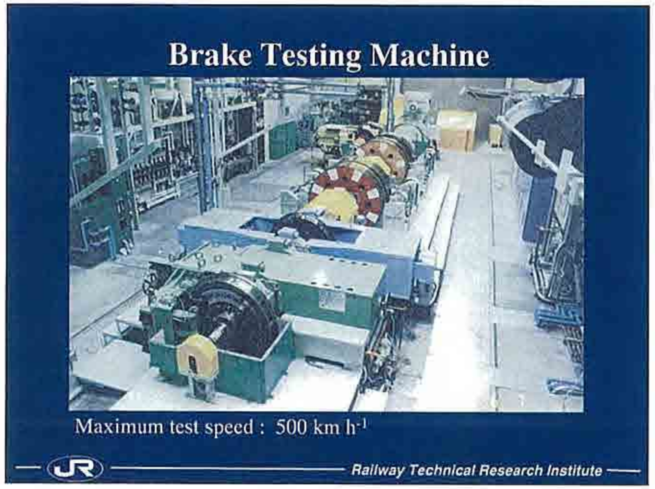
Brake Testing Machine
Maximum test speed : 500 km h-1
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Ride Comfort Simulator
Motion system and simulated passenger cab
Passenger cab (Interior)
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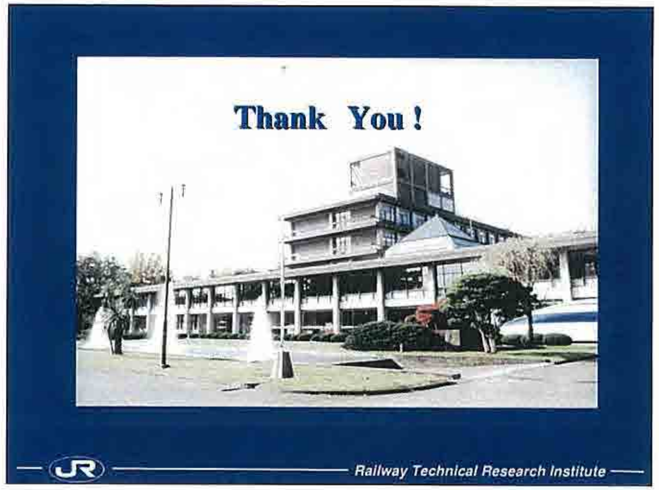
9


Thank You !
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Noise Problem of High-speed Train in Japan: -Development of Noise Reduction Technology-

Kiyoshi NAGAKURA
Railway Technical Research Institute, Japan
Environmental Engineering Division
Noise Analysis Group

Contents

- Introduction
- Environmental quality standards for Shinkansen railway noise
- Survey of Shinkansen railway noise
- Countermeasures against noise sources of Shinkansen train
- Conclusion

Introduction

Network of Shinkansen lines in Japan

Shinkansen Trains (Tokaido and Sanyo)

Shinkansen Trains (Tohoku and Joetsu)

JR — Railway Technical Research Institute

- Environmental quality standards for Shinkansen railway noise

JR — Railway Technical Research Institute

Environmental quality standards for Shinkansen railway noise

(the Environment Agency 1975)

Category of area	Standard value
I	$L_{pA,Smax}$ 70 dB or less
II	$L_{pA,Smax}$ 75 dB or less

Category I : the area for mainly residential use,

Category II : other areas, including commercial and industrial areas, where normal living conditions should be preserved.

JR — Railway Technical Research Institute

Temporary 75dB countermeasures

(the Environment Agency, since 1985)

Phase	Period	Target areas for 75 dB countermeasures	
		Tokaido and Sanyo Shinkansen lines	Tohoku and Joetsu Shinkansen lines
1	1985 -1994	Areas with highly dense houses continuously	Areas with highly dense houses, Areas with dense houses
2	1992 -1996	Areas with dense houses	Areas with nearly dense houses
3	1998 -2002	Areas with nearly dense houses	Areas with dense houses except those with sparse houses

JR — Railway Technical Research Institute

Temporary 75dB countermeasures and state of Shinkansen noise

After the third temporary 75dB countermeasures, the peak noise level $L_{pA,Smax}$ is less than 75dB <u>at all measured points in target areas</u> in Tokaido, Sanyo, Tohoku and Joetsu Shinkansen lines.

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- Survey of Shinkansen railway noise

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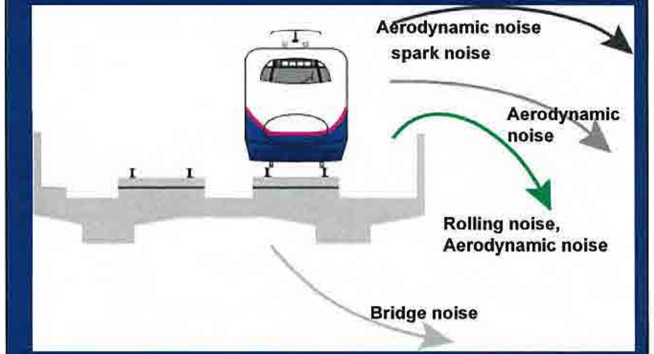

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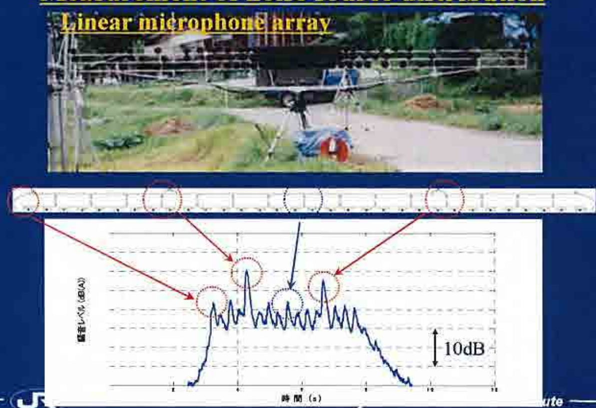
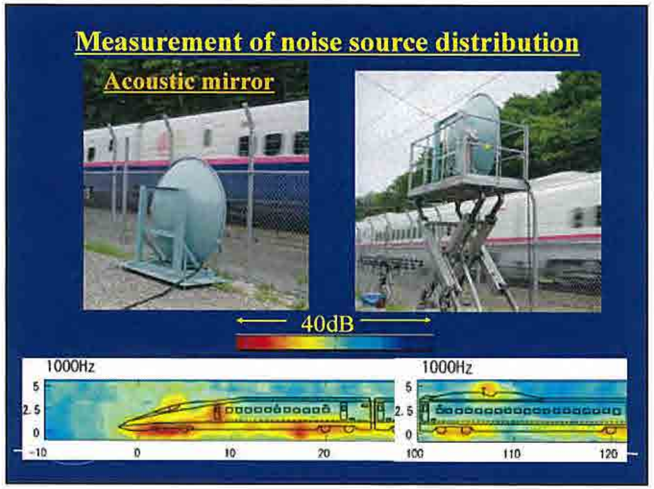
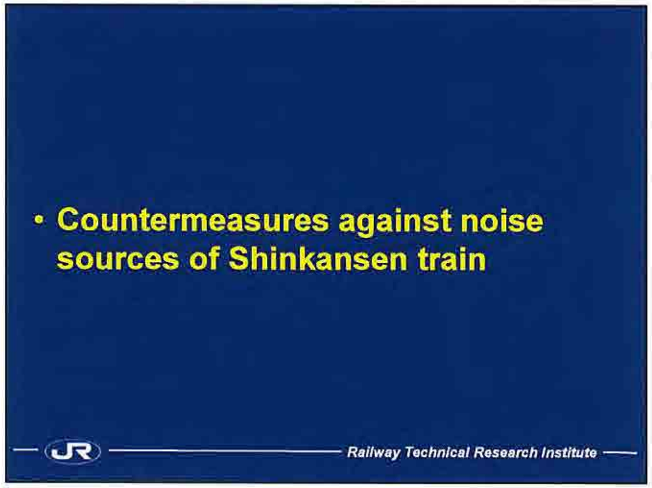
Measurement of noise source distribution





Measurement of noise source distribution
Acoustic mirror
40dB
1000Hz
1000Hz



• Countermeasures against noise sources of Shinkansen train
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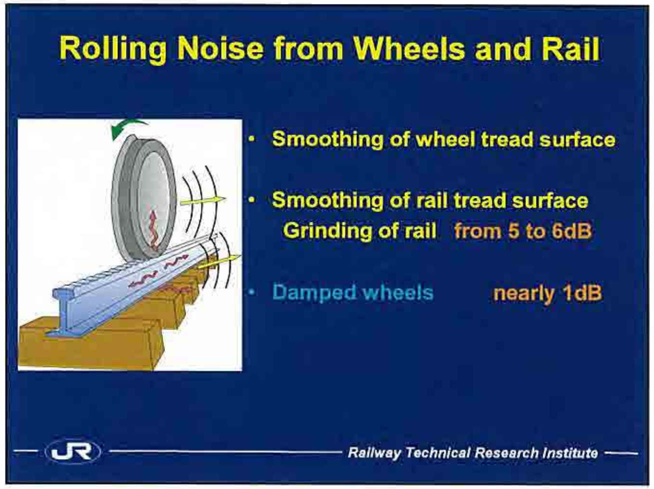
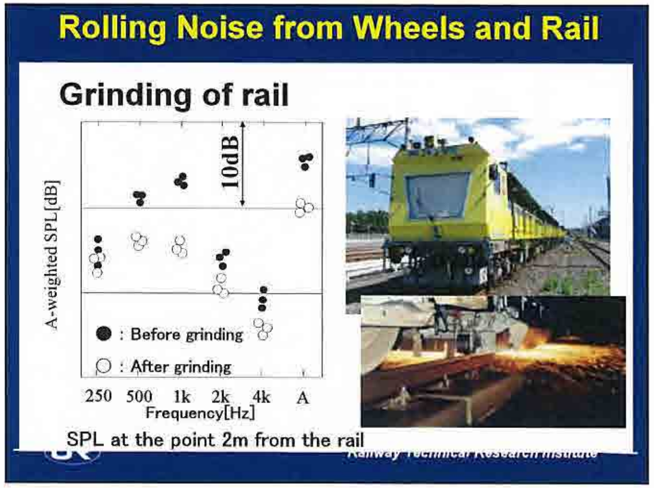


Rolling Noise from Wheels and Rail
• Smoothing of wheel tread surface
• Smoothing of rail tread surface
Grinding of rail from 5 to 6dB
• Damped wheels nearly 1dB
Railway Technical Research Institute



Rolling Noise from Wheels and Rail
Grinding of rail
A-weighted SPL[dB]
10dB
● : Before grinding
○ : After grinding
250 500 1k 2k 4k A
Frequency[Hz]
SPL at the point 2m from the rail

Noise from Concrete Bridge Structures

Countermeasures by reduction of external forces

- Smoothing of wheel tread surface
- Smoothing of rail tread surface
  Grinding of rail — nearly 5dB(A)
- Reduction of train weight

$\Delta L_N = 20\log_{10}(W_1/W_0)$

W_1 : Reduced weight, W_0 : Non-reduced weight

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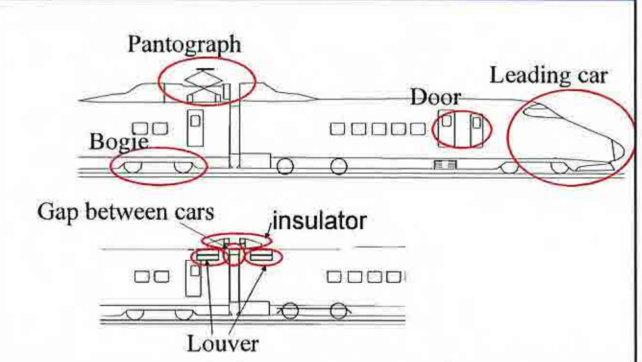
Aerodynamic noise sources



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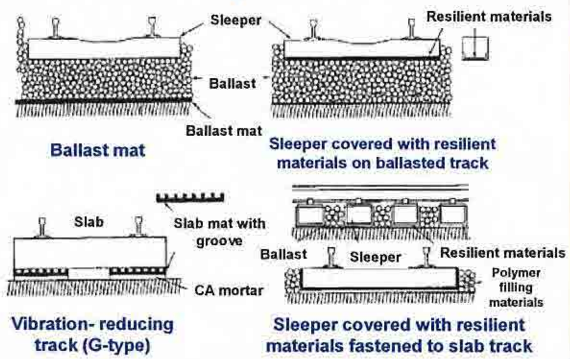
Countermeasures by insulation of vibration



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Aerodynamic noise sources

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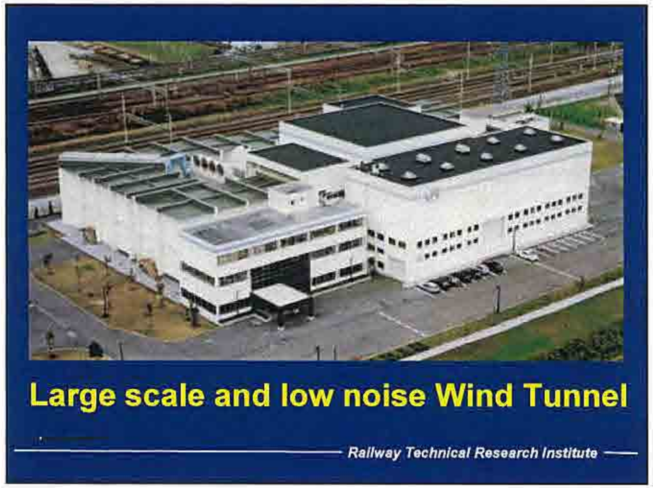
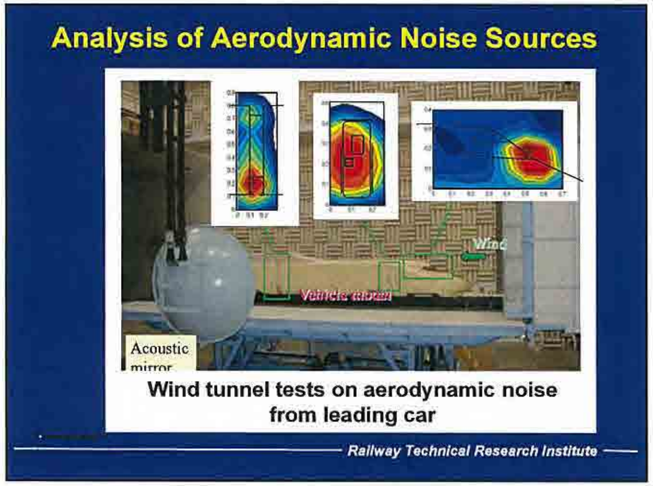
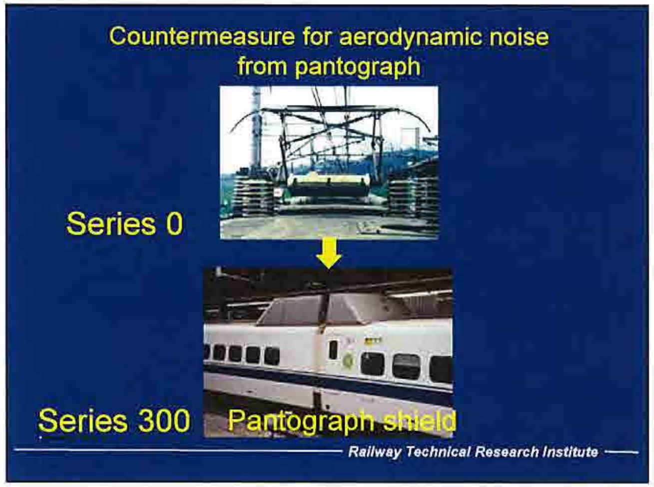
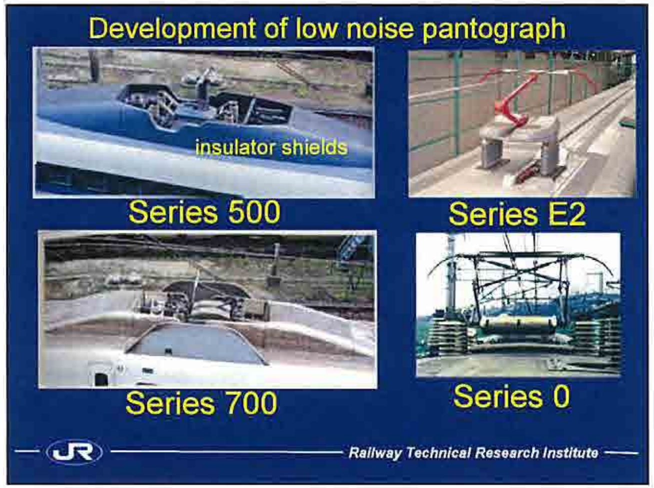
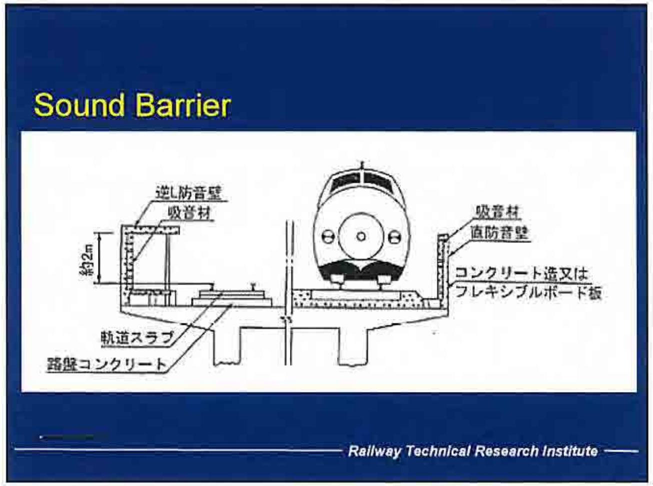

Large scale and low noise Wind Tunnel
Railway Technical Research Institute

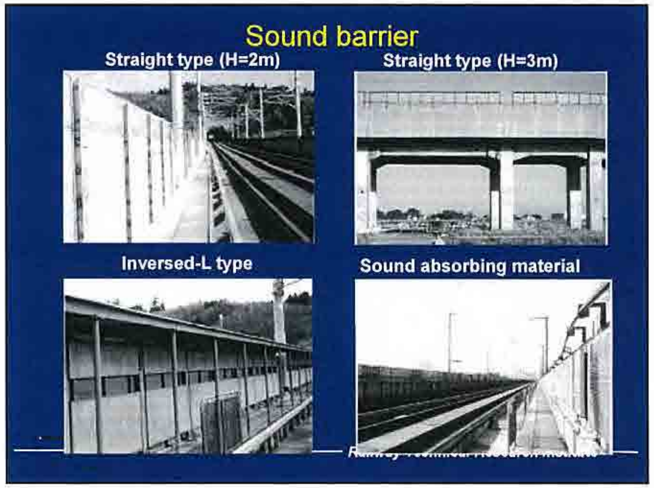

Countermeasures for Aerodynamic Noise
Series 100
Series 200
Smoothing car surface
Series 700
Series N700


Analysis of Aerodynamic Noise Sources
Wind
Vehicle model
Acoustic mirror
Wind tunnel tests on aerodynamic noise from leading car
Railway Technical Research Institute


Countermeasure for aerodynamic noise from pantograph
Series 0
Series 300
Pantograph shield
Railway Technical Research Institute


Development of low noise pantograph
insulator shields
Series 500
Series E2
Series 700
Series 0
Railway Technical Research Institute


Sound Barrier
逆L防音壁
吸音材
約2m
吸音材
直防音壁
コンクリート造又は
フレキシブルボード板
軌道スラブ
路盤コンクリート
Railway Technical Research Institute


Sound barrier
Straight type (H=2m)
Straight type (H=3m)
Inversed-L type
Sound absorbing material


Utilization of land plan
1964
2003
Presented by Central Japan Railway Company
Transition of land utilization along wayside
• Countermeasures by utilization of land plan are not powerfully promoted.
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Conclusion

A number of countermeasures against Shinkansen noise: bridge structure noise, rolling noise, spark noise and aerodynamic noise have been developed since Tokaido Shinkansen line was opened in 1964.

At present, the peak noise level can be kept less than 75dB specified in areas of category II in all Shinkansen lines.

Successive efforts are needed to achieve 70dB specified in areas of category I.

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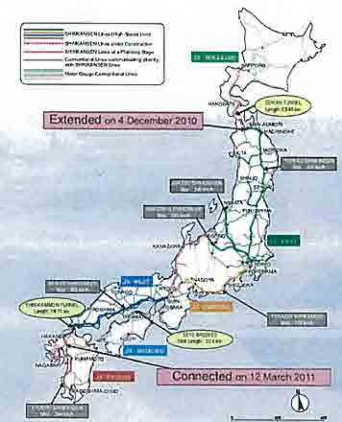
Recent Technologies of Train Control Systems in Japan

Ikuo WATANABE

Director
Research & Developent Promotion Division
Railway Technical Research Institute

Railway Technical Research Institute



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Recent technologies of train control systems in Japan

- Safety and Reliability
- System development
  - Traffic control
  - Interlocking
  - Automatic train protection
  - Train detection
  - Train radio

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Safety and Reliability

Safety technologies
- Redundancy
  (2 out of 3 CPUs, dual CPUs)
- Error detection
- Safety-fixed output

High reliability technologies
- Redundancy
  (dual CPUs)×2, 2 out of 3(dual CPUs)

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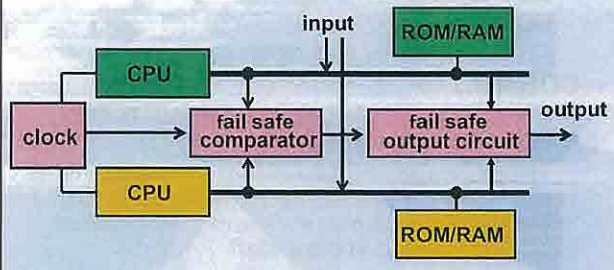
Safety technology
- dual computer architecture -



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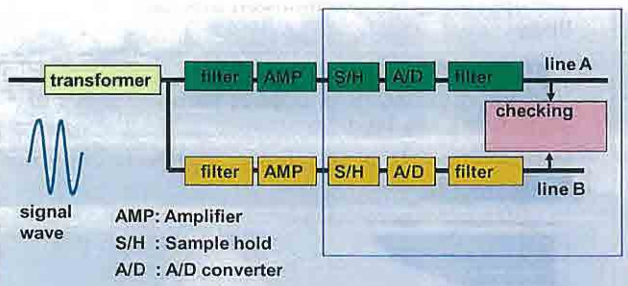
Safety technology
- analogue input circuit -



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Traffic control systems

- Integrated traffic control systems has been developed
  - COMTRACK
  - COSMOS
- COSMOS
  - transportation plan, traffic control, facility management, rolling stock management
  - Temporary speed restriction from dispatcher
  - Maintenance procedures are directly carried out between dispatchers and maintenance worker without station staff

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Electronic interlocking

- More than 1000 electronic interlocking systems are operating on Shinkansen and convention lines
- Improvement of microcomputer's performance
- Various architectures coping with the scale of station are realized
- Improvement of productivity, maintainability and facile installation.
  - CAD system generating interlocking table

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Automatic train protection

- ATC (cab signal, continuous transmission using track circuit)
  - Transmitting: track circuits
  - Signal : speed → distance to go
  - Data transmission: analog → digital
  - Brake control: multi-step → one-step
  - Data and process for train control: wayside → on-board

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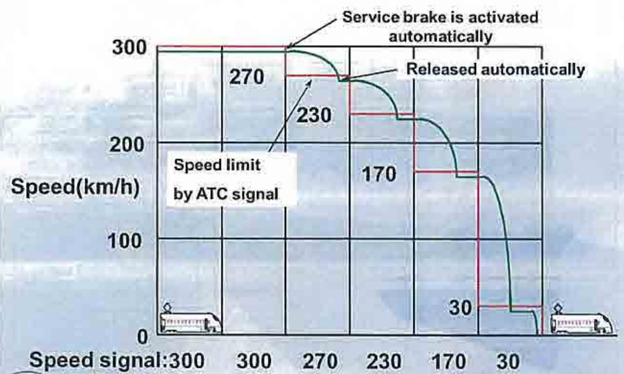
Conventional ATC



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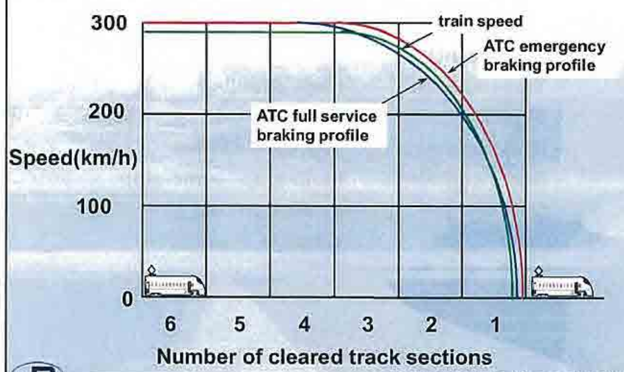
Digital ATC



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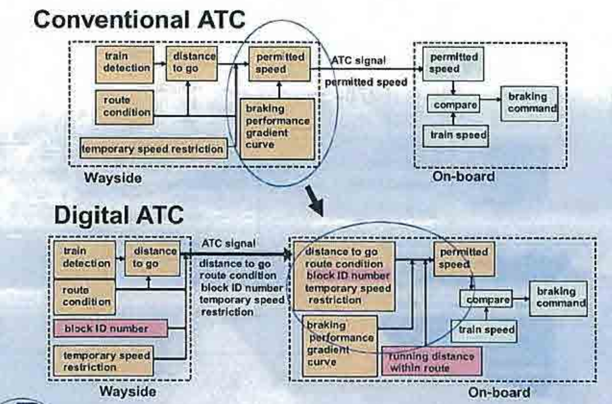

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Train detection

- Track circuits are widely used
  - prevention of shunting malfunction
  - EMC (electromagnetic compatibility)

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Train radio

- LCXs (Leaky Coaxial cables), instead of space-wave radio, are used for stable communication
- Digital transmission systems are introduced
- Specification

  frequency: 400MHz band
  service area: more than 99.99%
  bit error rate: less than 10^{-4}

- Information such as emergency information, character news are transmitted to trains

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Conclusion

- Various requirements
  - Train headway, Train speed
  - RAMS
  - Cost
  - Convenience
  - Environment-compatibility
- Technical circumstances
  - Power supply frequencies
  - Radio frequency bands

Progressive information technologies and network technologies should be utilized

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Track Technology for High Speed Line in Japanese Railways

Railway Technical Research Institute

Contents

1. Track technology division of the RTRI
2. The "Slab track," ballast-less track
3. Track inspection system
4. Track irregularity index

2. Track Technology Division

The track, one of the most important and fundamental railway structures, consists of rails, sleepers, ballast, road bed and other components. The quality of the design, components and construction of track greatly influences vehicle/track performance, maintenance cost of track and vehicles, running safety and riding comfort. It also governs the degree of noise, vibration and other environmental problems.

A key objective of the Division is the development of technologies and tools to evaluate and improve track structures and materials, often through advanced measurement, evaluation and maintenance of track geometry.

This Division is composed of the following four laboratories.

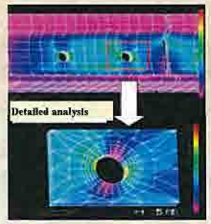
1) Track Structures and Components Laboratory
2) Track Structures and Geotechnology Laboratory
3) Track Geometry and Maintenance Laboratory
4) Rail Welding Laboratory

We also address advanced track technologies for railways in the future in cooperation with Track Dynamics Laboratory, Railway Dynamics Division.

Track Structures and Components Laboratory

Field: Research and development on rail, rail fastening, switch and crossing, expansion joint, mechanism of long welded rail

Products: Synthetic sleeper — Easy handling like wooden tie and high durability like concrete tie
Speed-up of split turnout — Application of curved crossing
Performance test of rail fastening --- Confirmation of reliability
Estimation method of fatigue life of rail joint — Application of FEM analysis



↑ 4-axle fatigue test machine for rail fastening
← FEM analysis for fatigue life around rail joint

Track Structures and Geotechnology Laboratory

Field: Research and development on low maintenance tracks for new and existing lines, reinforcement of ballast and roadbed and environmental friendliness.

Products: Type-D built-in track — Low noise and vibration track for newly constructed tracks
Paved track with asphalt injection — Low maintenance track for existing tracks
GEOCELL method — Improvement of poor roadbed and ballastbed
FWD method — Fast and simple estimation of the bearing index of roadbed

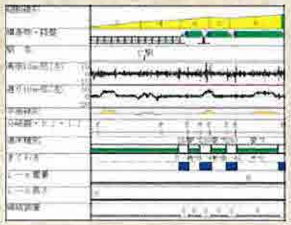
FWD method

Type-D built-in track

Track Geometry and Maintenance Laboratory

Field: Research and development on the track management method and track maintenance machines for safe and comfortable train operation

Products: Micro LABOCS database system for track maintenance — All-purpose system
Automated planning system for track tamping machines — Efficient repair
Track measuring system of a new concept — Low-cost and high performance
Track maintenance planning aid system — Effective track maintenance works



Prototype of inertia mid-chord system

Track maintenance chart by LABOCS

Rail Welding Laboratory

Field: Research and development on the method of welding for long welded rails, estimating method of welding quality aiming at the improvement of railway reliability.

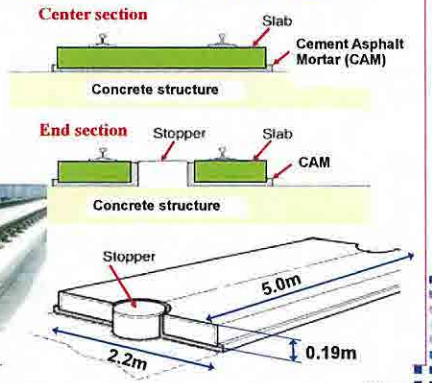
Products: Small-size gas pressure welding machine — Highly mobile performance
New gas-pressure welding method — High reliability irrespective of the skill of welders
High performance ultrasonic rail flaw detector — Aiming at high accuracy
Trimming of reinforced bar — Improvement of reliability of gas pressure welding

Usual | Improved

Gas burner for new gas pressure method

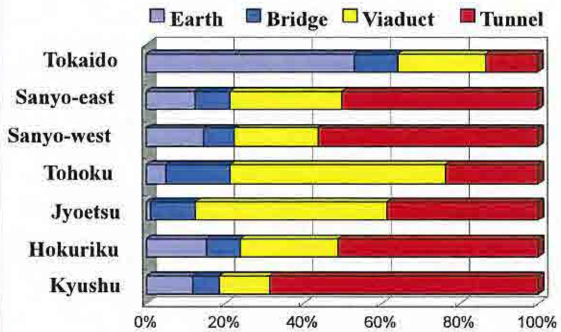
Welding by small-size welding machine

3. The "Slab track," ballast-less track

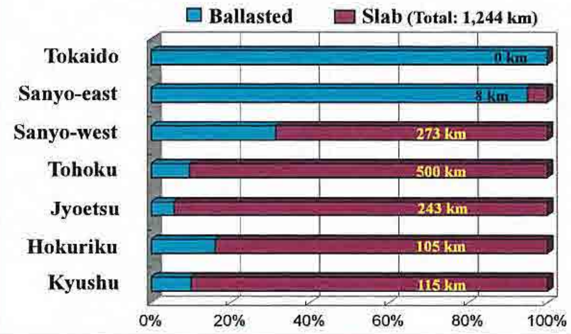


Slab tracks

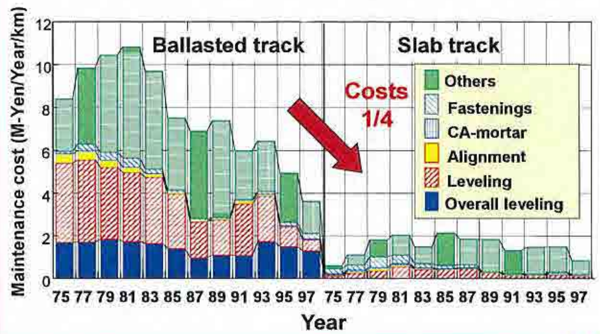
Infrastructure of Shinkansen



Track structure of Shinkansen



Comparison of maintenance costs



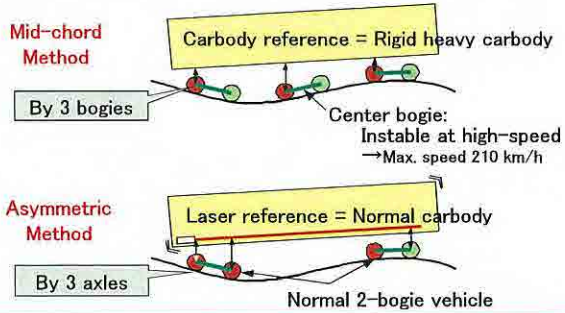
Comparison of performance

Items	Ballasted	Slab
Construction cost	Good	Poor
Construction speed	Even	Even
Construction precision	Even	Even
Durability	Poor	Good
Elasticity	Good	Poor
Maintainability	Even	Even
Maintenance Cost	Poor	Good

3. Track inspection system
"Doctor Yellow," for the Shinkansen

Started to use in 1975.
Maximum speed was 210km/h.

Difference between Mid-chord and Asymmetric-chord Measuring Method



2-bogie Track Inspection Cars

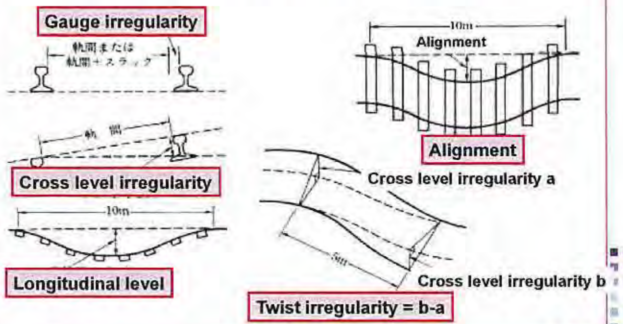
Same speed as commercial train (270, 275km/h)

JR-Central 923
"New Doctor Yellow"

JR-East E926 "East-i"
(For standard gauge lines)

Inertia versine inspection device

Definition of track irregularity



Track irregularity index for Meter gauge

Type / Rank / Category	Alert Limit 1st Rank	Alert Limit 2nd Rank	Alert Limit 3rd Rank	Alert Limit 4th Rank	Immediately Action Limit 1st Rank	Immediately Action Limit 2nd Rank	Immediately Action Limit 3rd Rank	Immediately Action Limit 4th Rank
Gauge	+10 -5				15(9) 200<=R<600 20(14) another			
Cross level	11 (7)	12 (8)	13 (9)	16 (11)				
Height	13 (7)	14 (8)	16 (9)	19 (11)	23 (15)	25 (17)	27 (19)	30 (22)
Street	13 (7)	14 (8)	16 (9)	19 (11)	23 (15)	25 (17)	27 (19)	30 (22)
Twist					23 (18)			

()In the inside, it is a unloaded value.

Track irregularity index for Shinkansen (JR-EAST)

Category	unit	Immediately Action Limit Above 275km/h	More than 245km/h	More than 210km/h	More than 160km/h	More than 110km/h	More than 70km/h	Less than 70km/h
Gauge	mm	+8 −6	+9 −6	+10 −7	+13 −8	+15 −9	+20 −9	+20 −9
Cross Level	mm	7	8	10	13	15	20	20
Longitudinal Level	mm/10m	10	12	14	16	21	24	30
Alignment	mm/10m	6	7	8	9	11	13	30
Twist	mm/2.5m	7	8	10	13	15	20	24

Track irregularity index for Shinkansen (JR-EAST)

Long chord versine (Alert Limit)

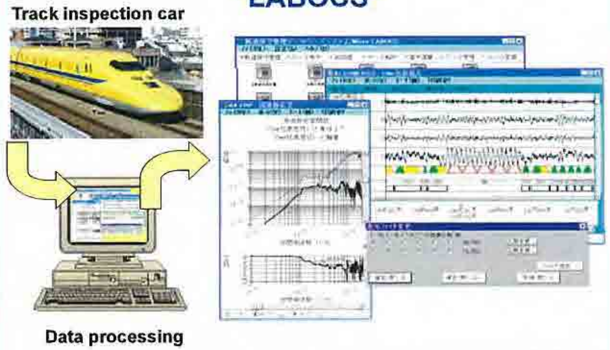
Category	20m	40m
Longitudinal level	8mm	7mm
Alignment	7mm	5mm

EN13848-5 （excerpt）

	Immidiately Action Limit[mm]			
	Longitudinal Level		Alignment	
Velocity[km/h]	3＜λ≦25	25＜λ≦70	3＜λ≦25	25＜λ≦70
V≦80	28	-	22	-
80＜V≦120	26	-	17	-
120＜V≦160	23	-	14	-
160＜V≦230	20	33	12	24
230＜V≦300	16	28	10	20

Amplitude of actual track irregularities

Track maintenance database system "LABOCS"



Track Maintenance Technology in Japanese Railways

Railway Technical Research Institute