Investigation of Derailment Accidents on Shinkansen Lines due to Great Earthquakes

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Summary

- Recent Great Earthquakes in Japan
- Major counter-measures for the earthquakes
- Shinkansen Derailment Accident in Kumamoto in 2016

  Summary of accident investigation report

Recent Great Earthquakes in Japan

1995 Kobe: The great Hanshin-Awaji Earthquake

An earthquake of magnitude 7.2 with the hypocenter at the depth of 14km under the northern part of Awaji Island occurred at 5:46 am on January 17, 1995. Many railway structures were collapsed. No derailment occurred.

2004 Joetsu: The mid Niigata prefecture Earthquake

An earthquake measuring 6.8 on the Richter scale struck the Chuetsu region of Niigata prefecture at 17:56 on October 23, 2004. It was an inland earthquake whose hypocenter was at the depth of 13 km. The Shinkansen train Toki 325 was derailed while running at a velocity of 200km/h. That was the first Shinkansen derailment accident caused by the earthquake.

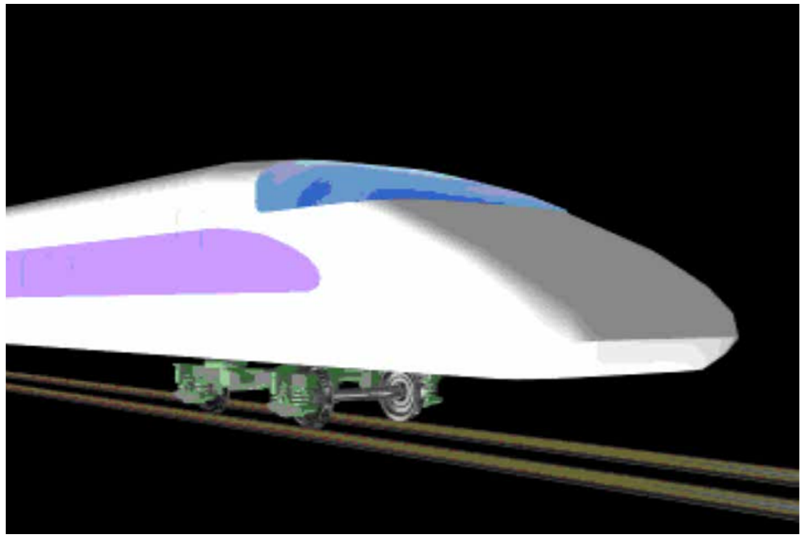
2011 Tohoku: The Great East Japan Earthquake

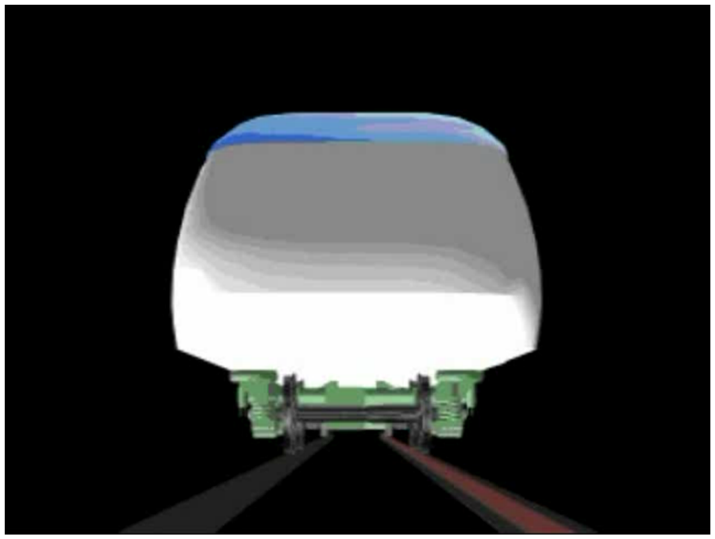
The 2011 off the Pacific coast of Tohoku Earthquake struck the largest area of Eastern Japan along the Pacific Ocean at 14:46 on 11 March. The first hypocenter was in offshore of Miyagi Prefecture, about 172 km distant from Sendai Station, ad 24 km in depth. Its moment magnitude was 9.0, and the maximum seismic intensity of 7 was observed in northern Miyagi Prefecture. The test 7932B train was derailed at the speed of 72 km/h.

2016 Kumamoto: Explained later

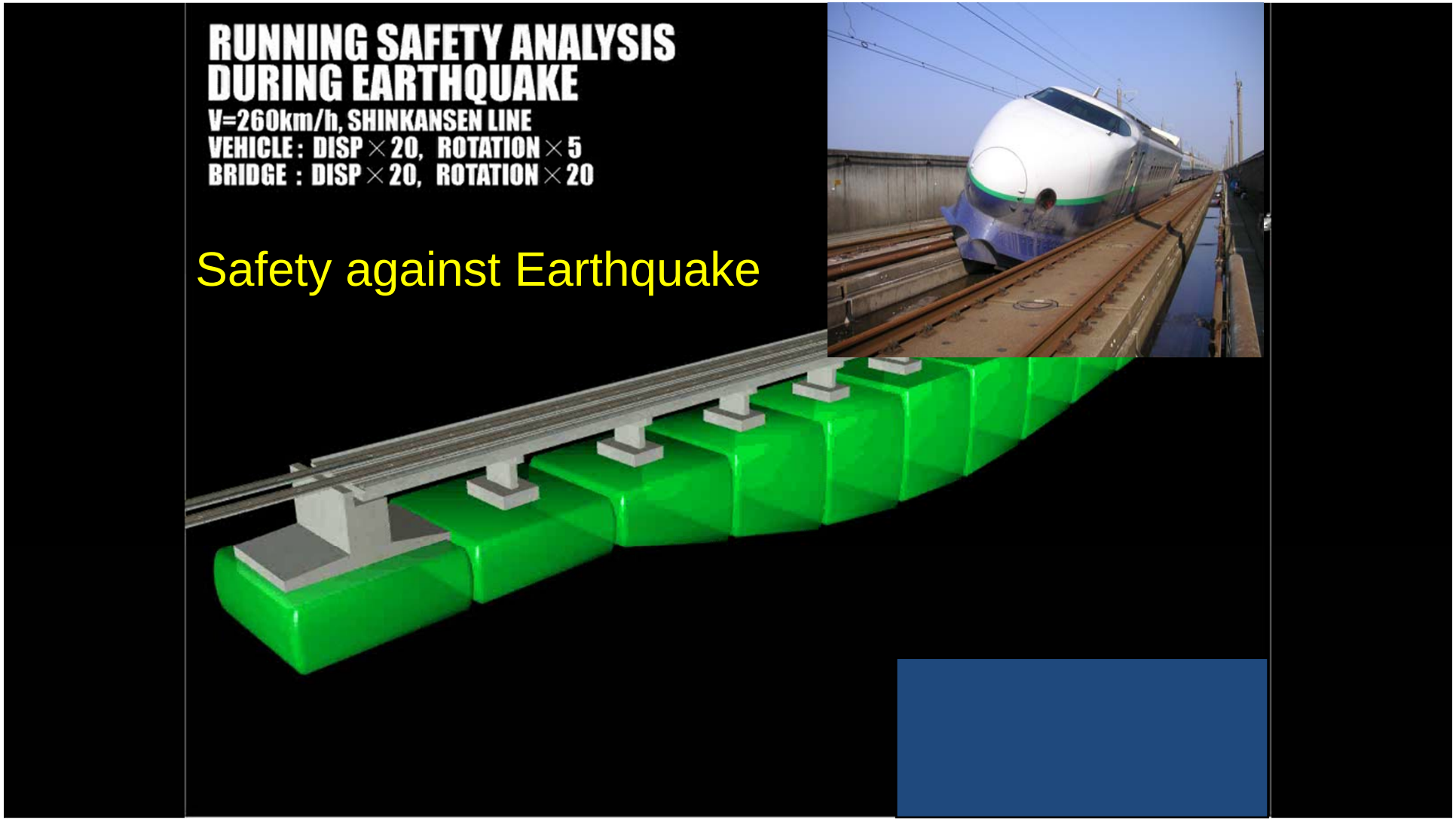
Derailment of Shinkansen trains

"Rocking derailment“ caused by repeated earthquake lateral motion when the right or left wheel goes up alternately moving laterally to induce derailment.

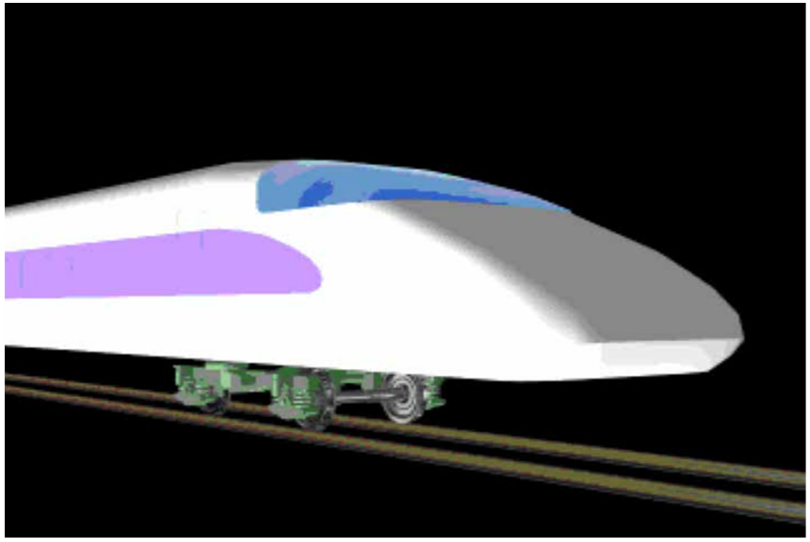




Simulation of Dynamics of Rolling Stocks and Structures

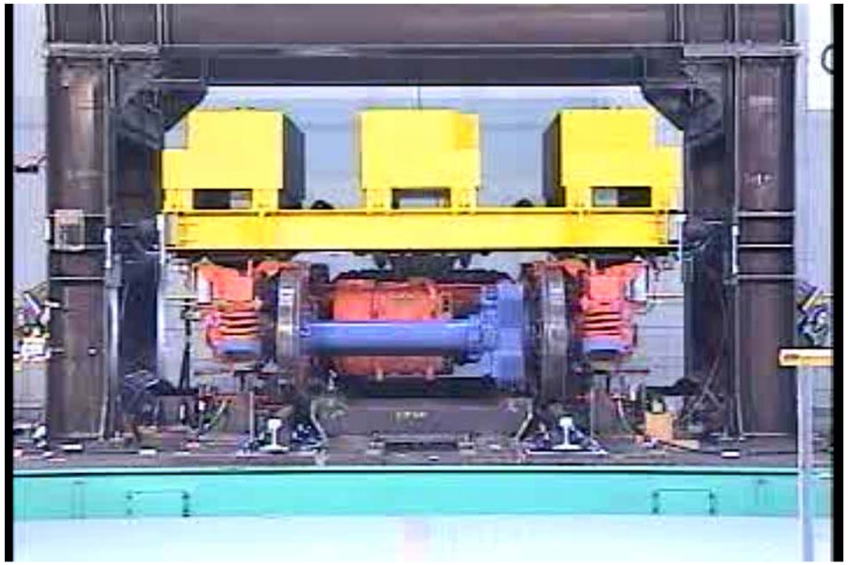


Analysis of Dynamic Behavior of Vehicle during Earthquake



CG animation of simulation

Full-scale experiment of actual truck



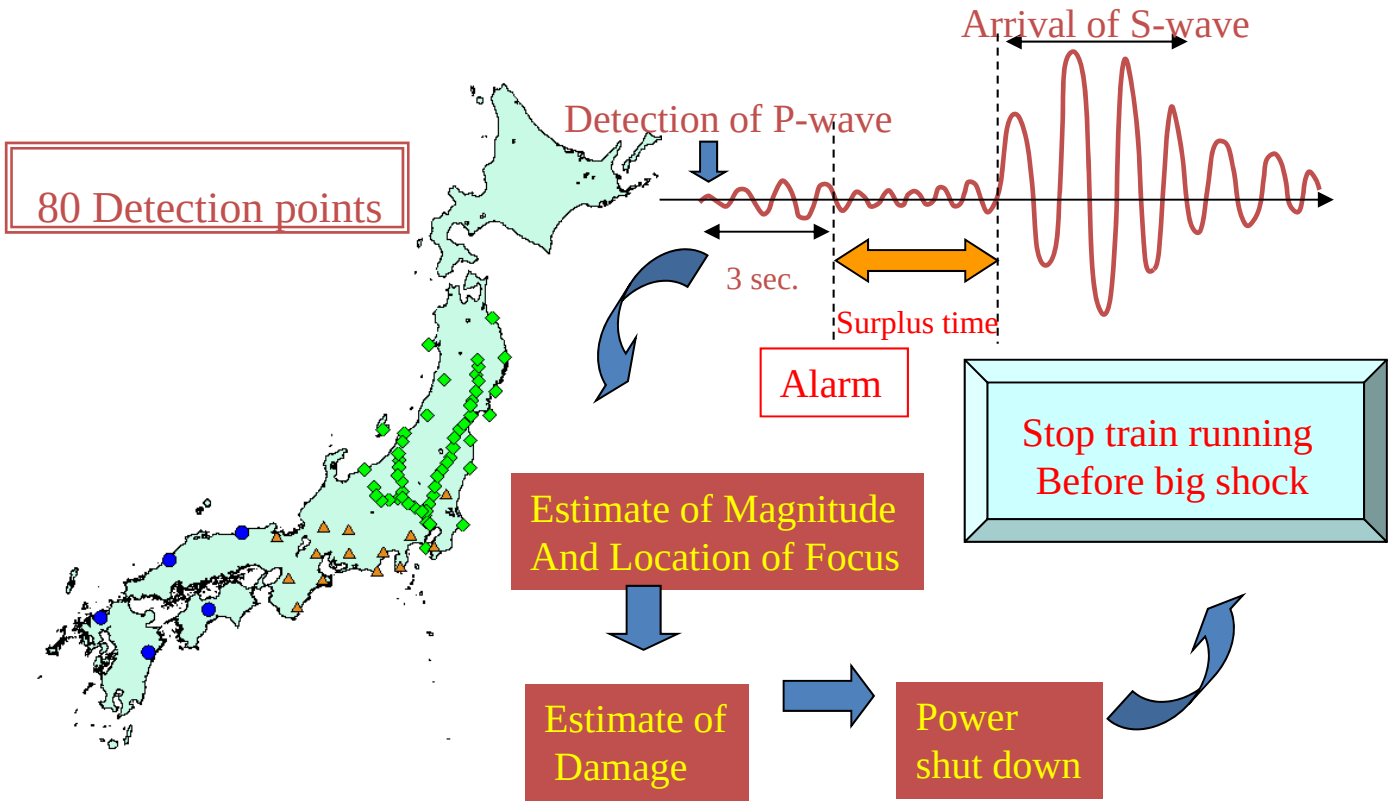
Major counter-measures for the earthquakes

- Improvement of the early earthquake alert system for Shinkansen to stop trains immediately

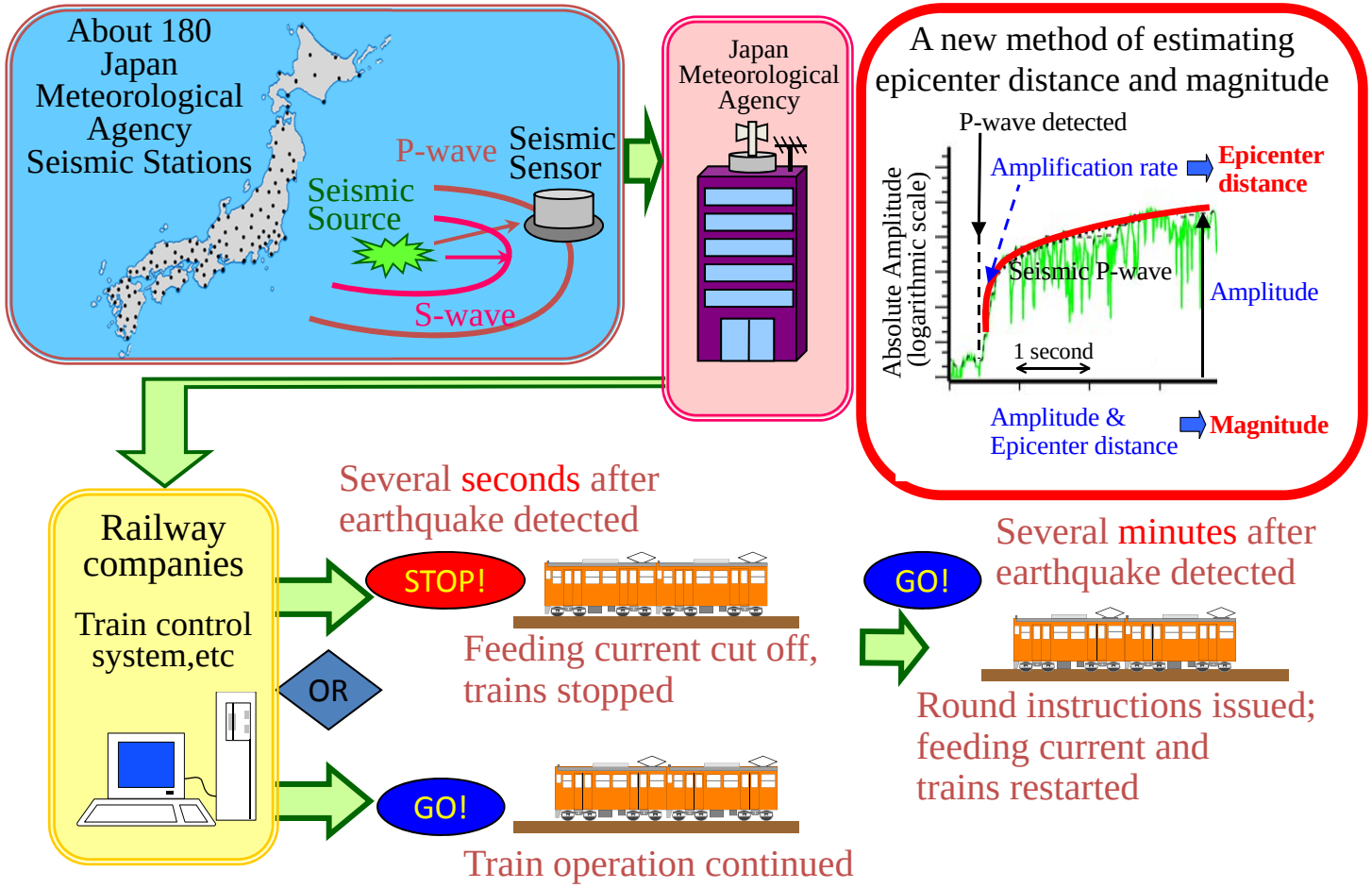
- Seismic reinforcement of elevated bridges

- Prevention of derailment and secondary accidents after the derailment

Urgent **E**arthquake **D**etection & **A**larm **S**ystem



A New System for Early Earthquake Warning



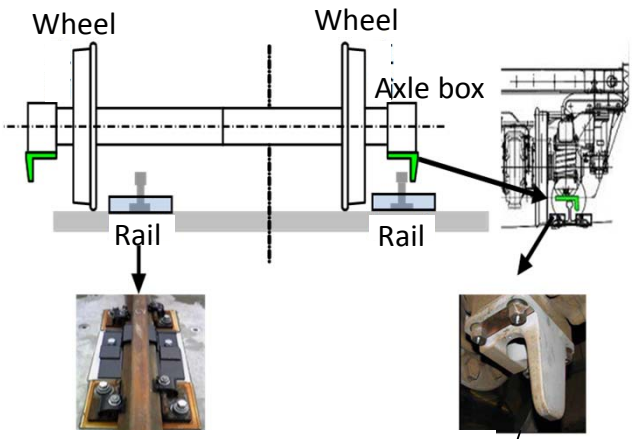
Seismic reinforcement of elevated bridges

- Railway companies reinforced rigid-frame elevated bridge columns which were susceptible to shear failures.

- The design guideline on earthquake-resistant construction of structures was revised. In consideration of the immense damage caused by the earthquakes, it is extremely important to realize further reinforcement and improvement of railway infrastructure including existing facilities.

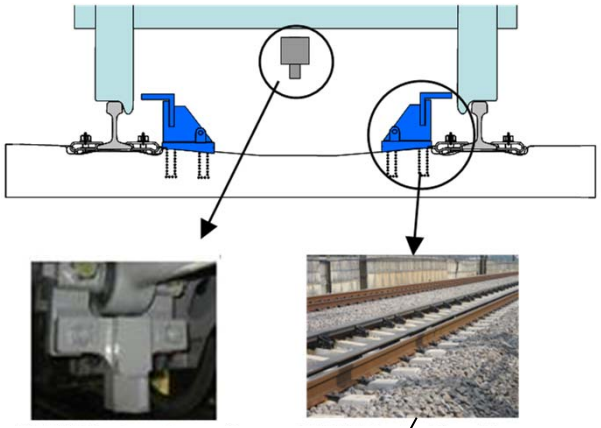
Example of reinforced columns

Prevention of derailment due to earthquakes and secondary accidents after the derailment



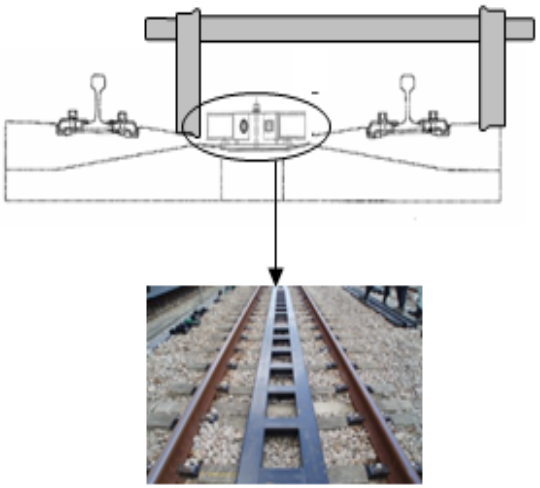
Rail rollover prevention devices

L-shaped car guide



Post derailment stopper

Anti-derailing guard



Deviation prevention guards

Summary of the Shinkansen Derailment Accident in Kumamoto, 2016

1. Railway Operator : Kyushu Railway Company
2. Accident Type : Train derailment
3. Date and Time : About 21:26, April 14, 2016
4. Location : At around 99,160m from the origin at Hakata station,
   between Kumamoto station and Kumamoto General Train Depot.
5. Train : The 5347A train, composed of six railway vehicles,
   started from Hakata station bound for Kumamoto station.
6. Injuries to persons : None
7. Summary

The 5347A train departed from Kumamoto station on schedule at 21:25 Japan Standard Time (JST: UTC+9 hr).

While the train was running at about 78 km/h, the driver of the train felt vertical jolts as if the earth were heaving upward, then turned off the notch and applied emergency brake operation immediately.

After the train had stopped, the driver got off the train and checked underfloor condition of the vehicles and found that all six vehicles were derailed.

Only the driver was onboard the train, there was no injured person.

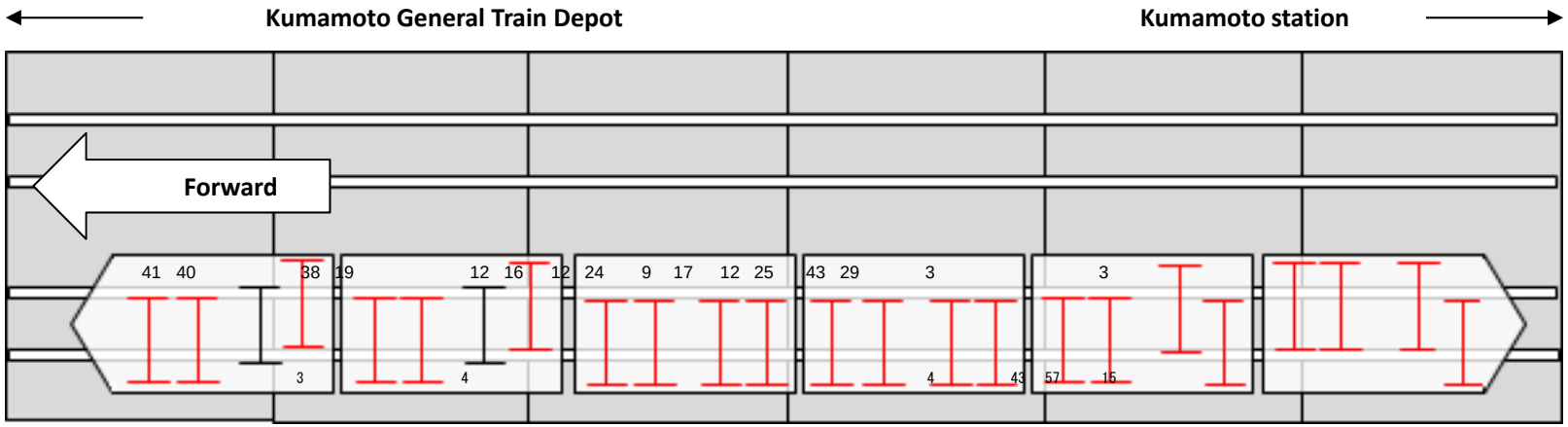
Here, the earthquake of magnitude 6.5, one of the 2016 Kumamoto Earthquakes, that the hypocenter was in depth of about 11 km in Kumamoto district, Kumamoto Prefecture, had occurred at about 21:26, April 14, 2016. The maximum seismic intensity seven was observed in Mashiki Town, Kumamoto Prefecture.

Summary of the vehicles

The model : series 800 Shinkansen

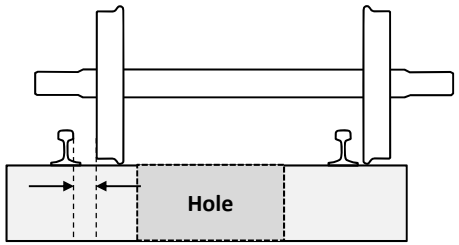
The train composed of six railway vehicles. (set U005)

The conditions of each axles after the accident



(Note)

- **The axles in black remained on the rail.**
  The axles in red were derailed.
- **The number next to each axle shows distance between the inside of rail head and the outside of the wheel.**
  (see the picture on the right side. Unit : cm)



Detachment from the rail

The conditions of the train

There were displacements in the transverse direction between each vehicle.
As for the leading vehicle of the train, the body shifted to the left by around half of the track gauge and the longitudinal center of the vehicle was on the left rail.
The train stopped at around 99,461 m from the origin at Hakata station.

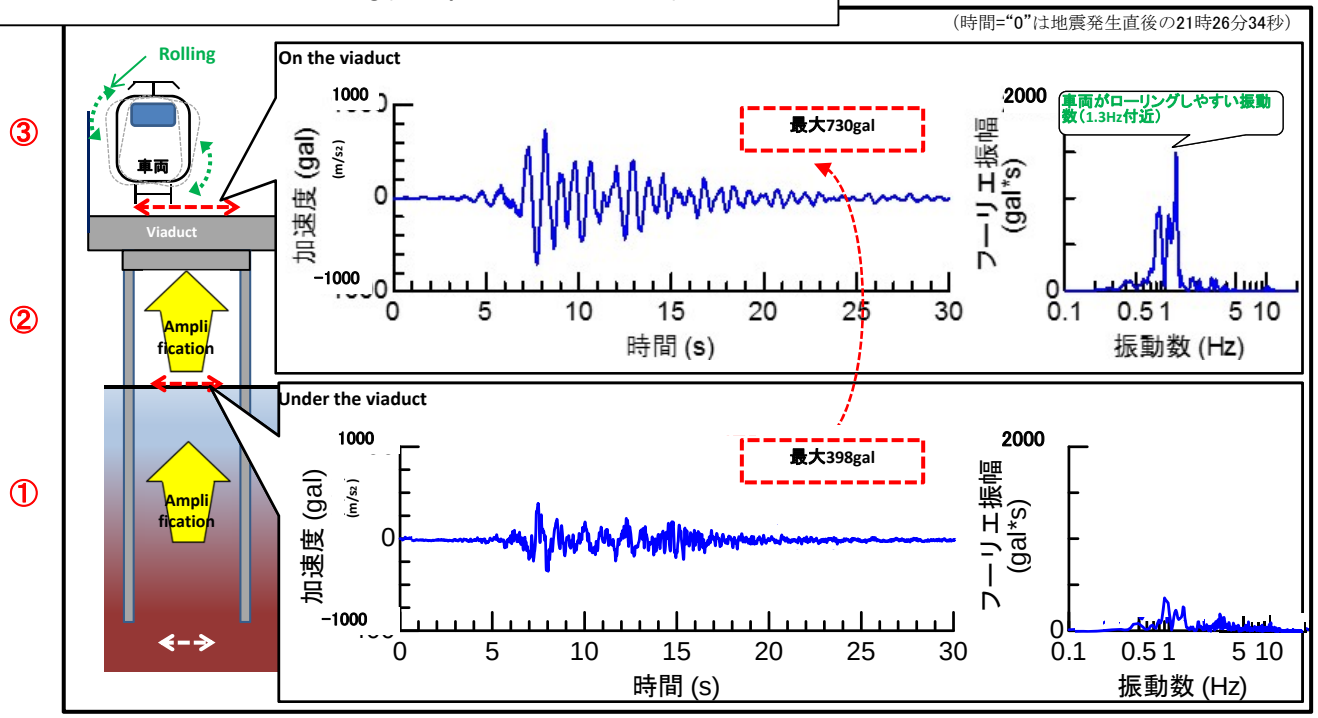
The conditions of the leading vehicle

The analysis of the derailment

Assumption of progress of the derailment (simulation)

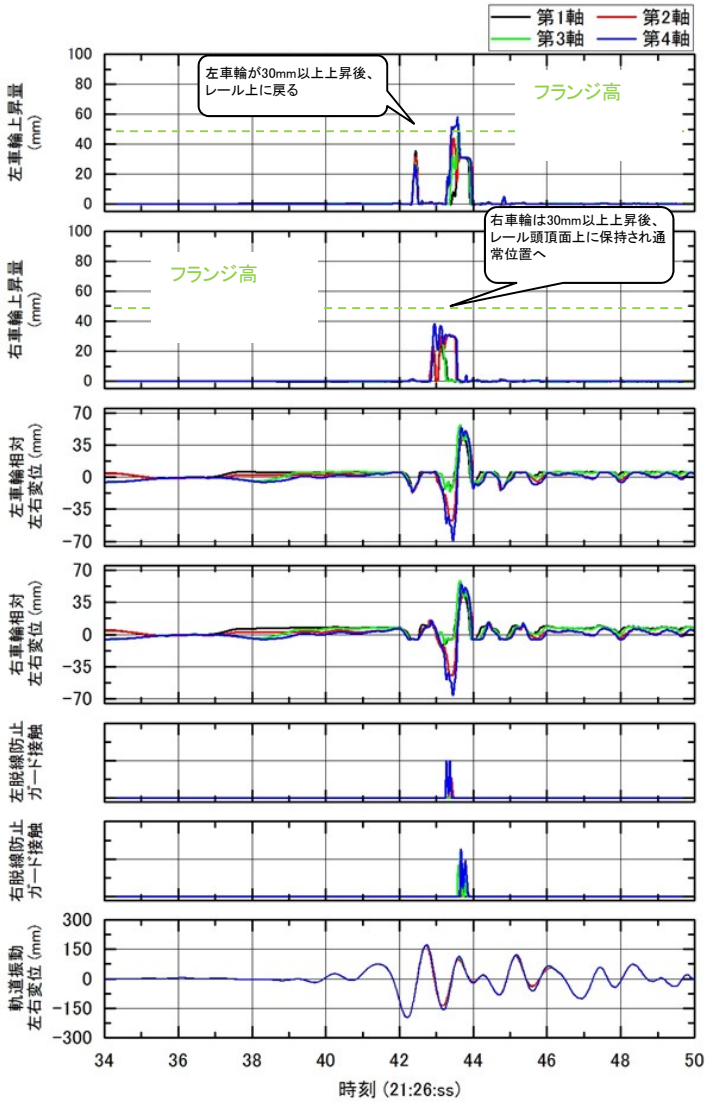
① The violent shakes in lateral direction to the track acted on just under the viaduct around the accident site caused by the amplified ground motion.
② The amplified rolling motion in the frequency range (around 1.3Hz) to promote rolling of vehicles acted on the track surface caused by the amplified motion in the viaduct.
③ Many axles was derailed almost the same timing, because each vehicle in the train rolled significantly.

The conditions of the rolling (example of estimated value)



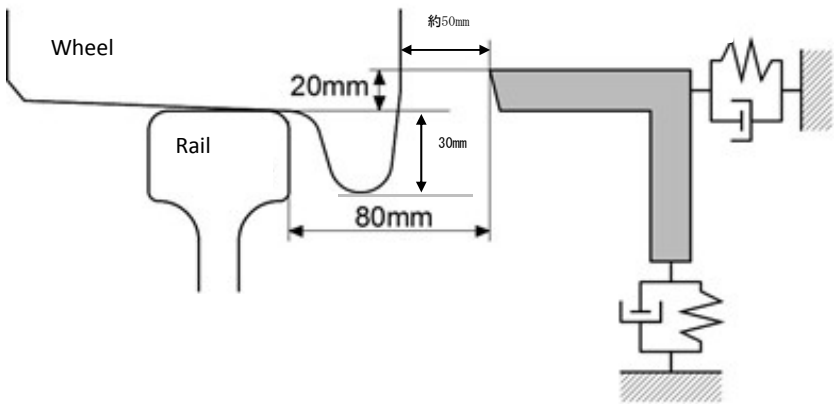
The analysis of the derailment

○Example of the analysis of vehicle movements when anti-derailing guard are installed. (the leading vehicle)



If anti-derailing guard are installed, no derailment would occur as the result.

It is somewhat likely that the risk of derailment could have been reduced if anti-derailing guard had been installed.



The model of anti-derailing guard

Conclusion

- Recent Great Earthquakes in Japan

  Counter-measures for big earthquakes were taken gradually.

- Major counter-measures for the earthquakes

  Early alert systems were improved

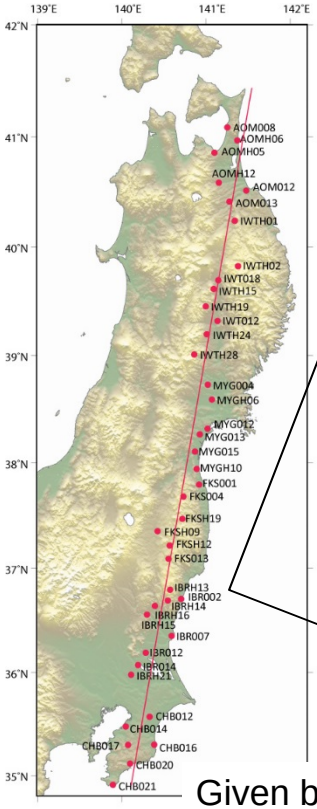
  Railway structures were reinforced.

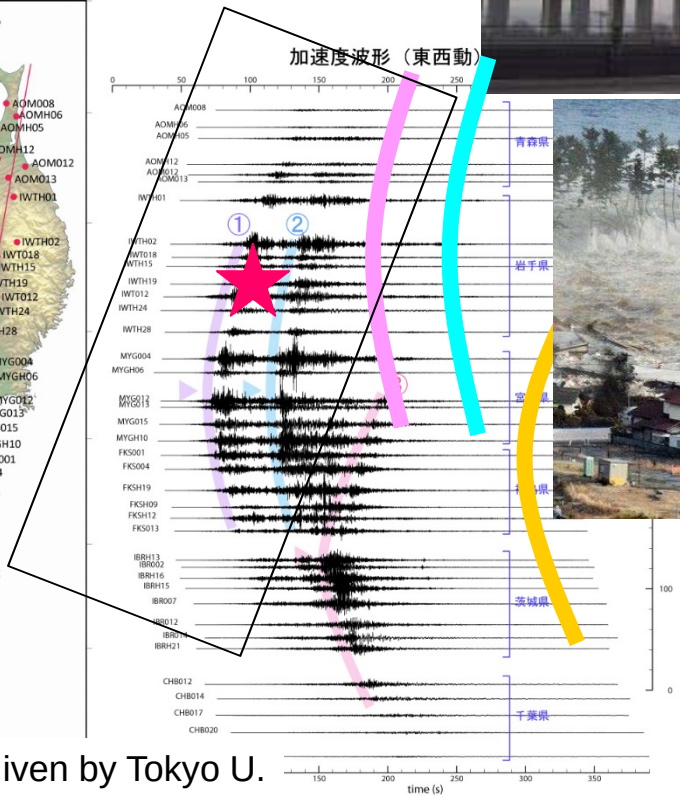
  Derailment due to earthquakes and secondary accidents after derailment were prevented by special devices.

- Shinkansen Derailment Accident in Kumamoto in 2016

  Summary of accident investigation report

How was the area attacked by the seismic waves?





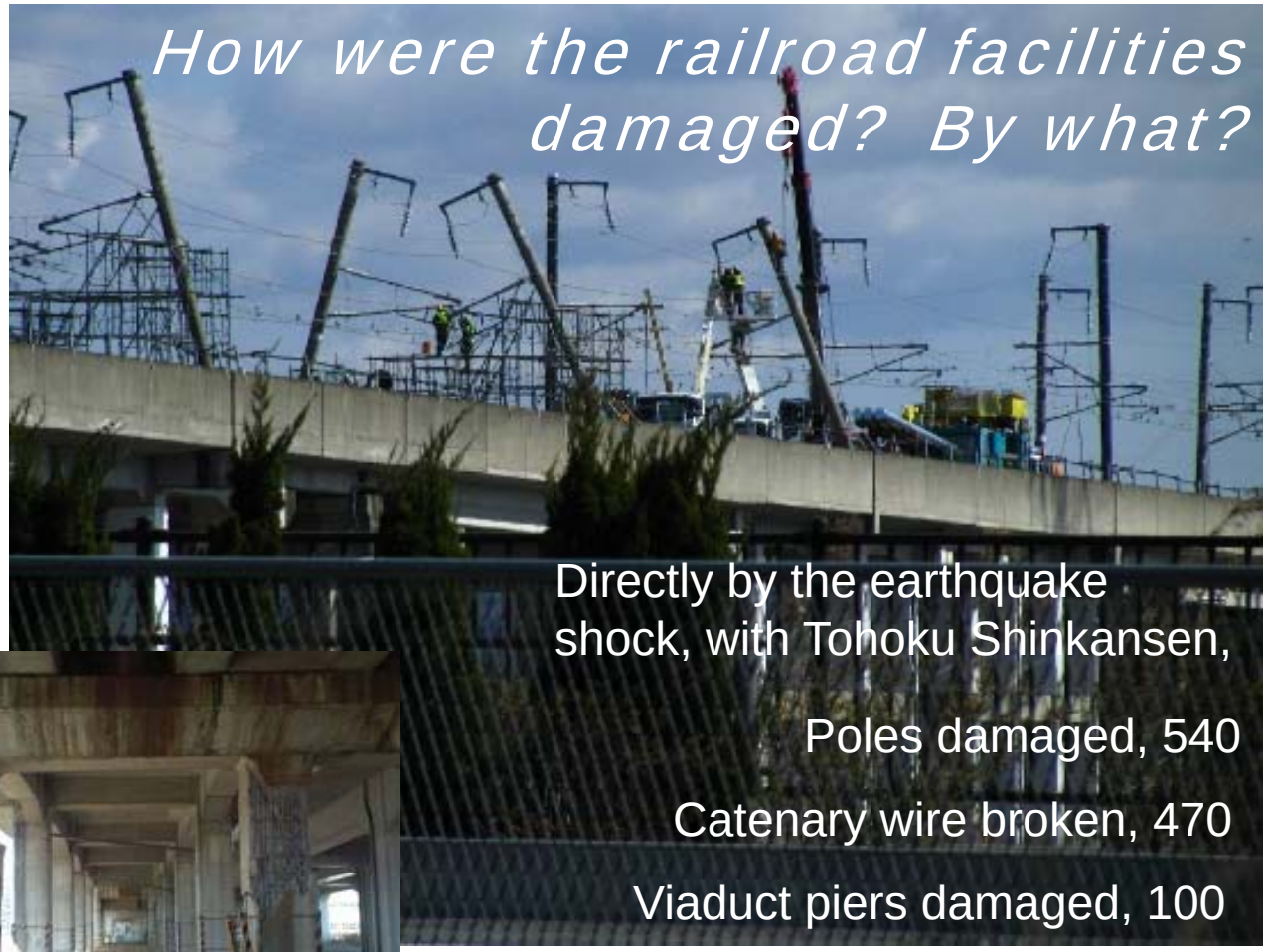
Given by Tokyo U.

Dead, 14,786

Lost, 10,271

Injured, 5,279

How were the railroad facilities damaged? By what?



Directly by the earthquake shock, with Tohoku Shinkansen,

Poles damaged, 540

Catenary wire broken, 470

Viaduct piers damaged, 100

Given by JR-East

Rail irregularity generated, 20

Power sub-stations malfunctioned, 10

How did the Pacific-Rim Shinkansen services come up from Kagoshima to Aomori for 2000.8 km in 2011?