FAILURE MECHANISM OF THE FURYO DAIICHI BRIDGE IN THE 2016 KUMAMOTO EARTHQUAKE

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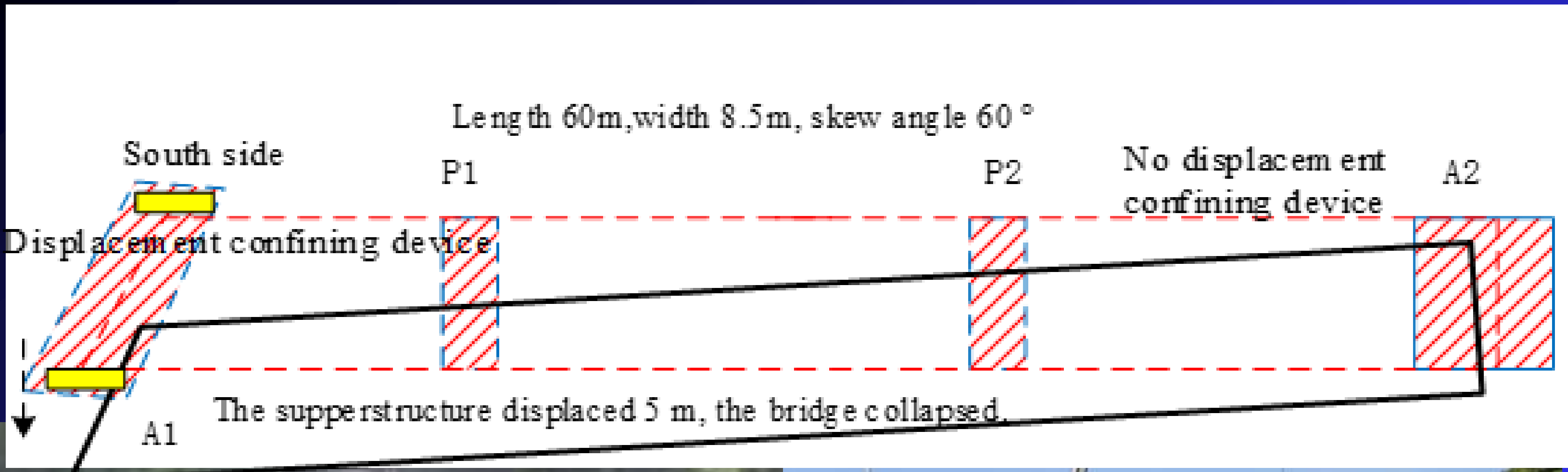
Background:

1. Furyo Daiichi was an overbridge crossing over the Kyushu Expressway.
2. The bridge collapsed onto the expressway due to a large displacement to the perpendicular direction.

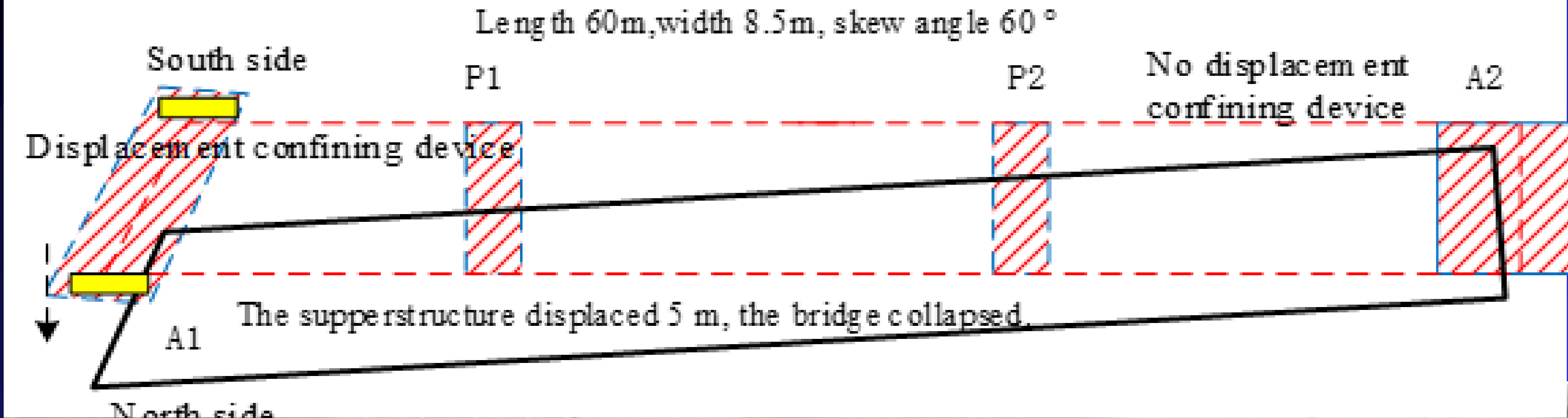
Objectives:

1. A possible damage mechanism inferred from the sustained damage.
2. Dynamic analysis to identify an actual failure mechanism.



1.Span length 60m, and P1,P2 rocking piers

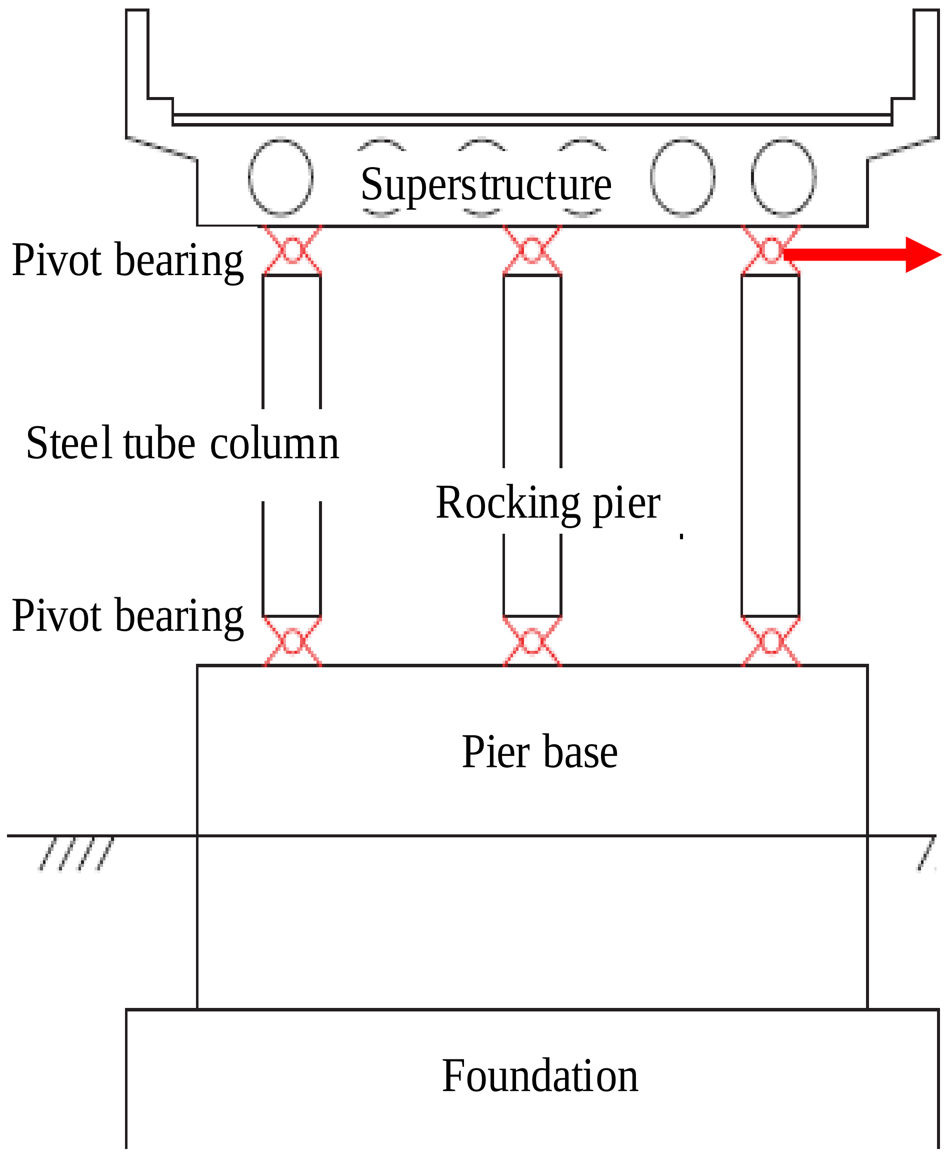
2.Supperstructure displaced 5m,bridge collapsed.

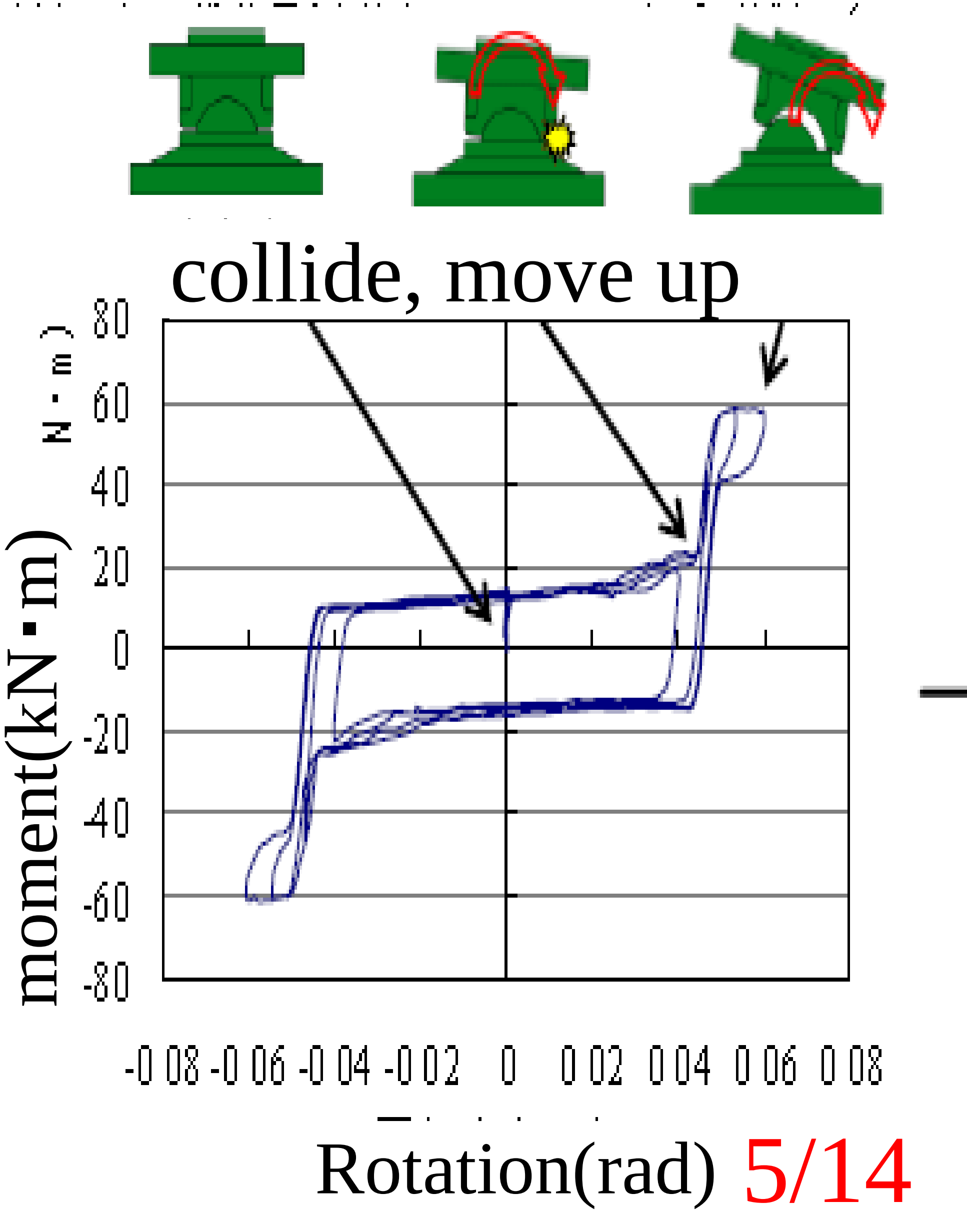


1.Skewed superstructure collided against the displacement confining device.

2.A punching shear failure occurred at the connection.

1.When rocking piers were displaced 14.7cm (rotation of the pivot bearing 0.06rad),the bridge collapsed.





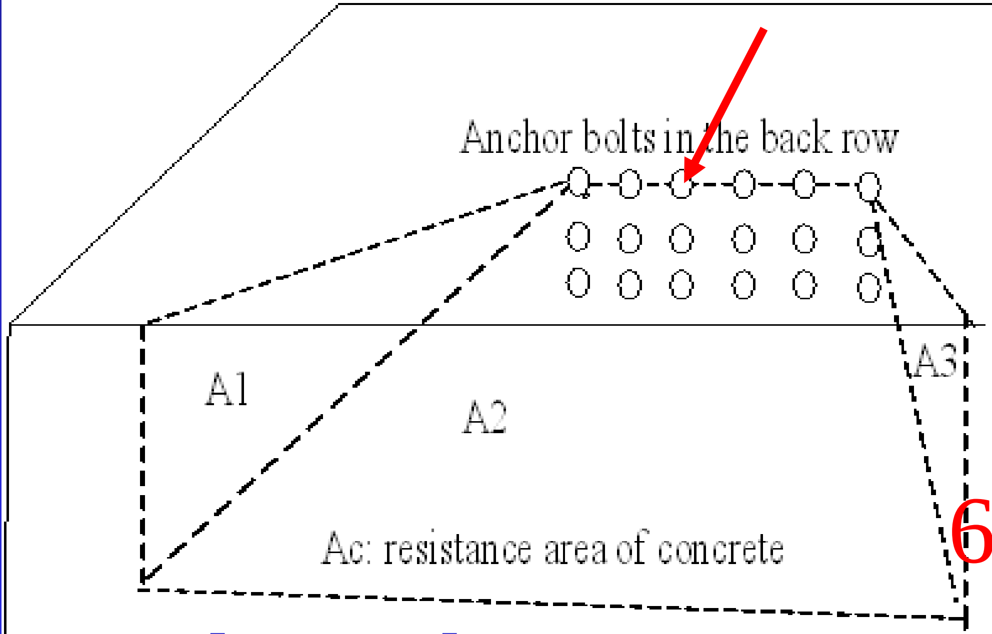
I. Punching shear resistance

(τc : $0.22 N/mm^2$)

1076kN(1.7Rd)

II. Design seismic force=3・kh・Rd = 1554kN

Resistance is smaller than force.



Punching shear resistance

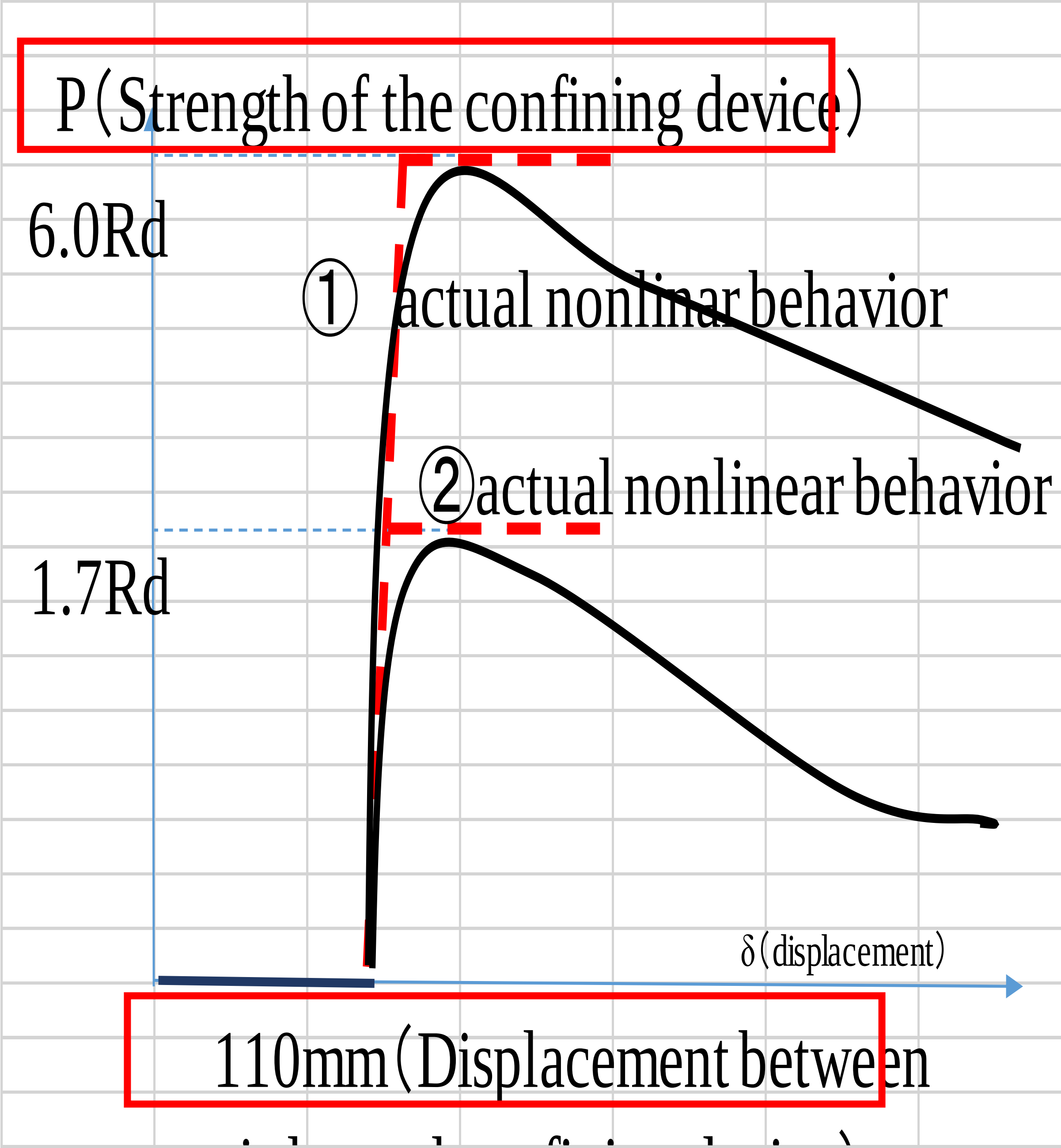


Fig.Resistance of confining device

1. Punching shear resistance is small.
2. 150mm: allowable displacement of girder
3. 110mm: clearance between girder and confining device.

AbutmentA1：elastic beam element

Plate bearing：nonlinear spring element

Displacement of confining device: nonlinear spring element

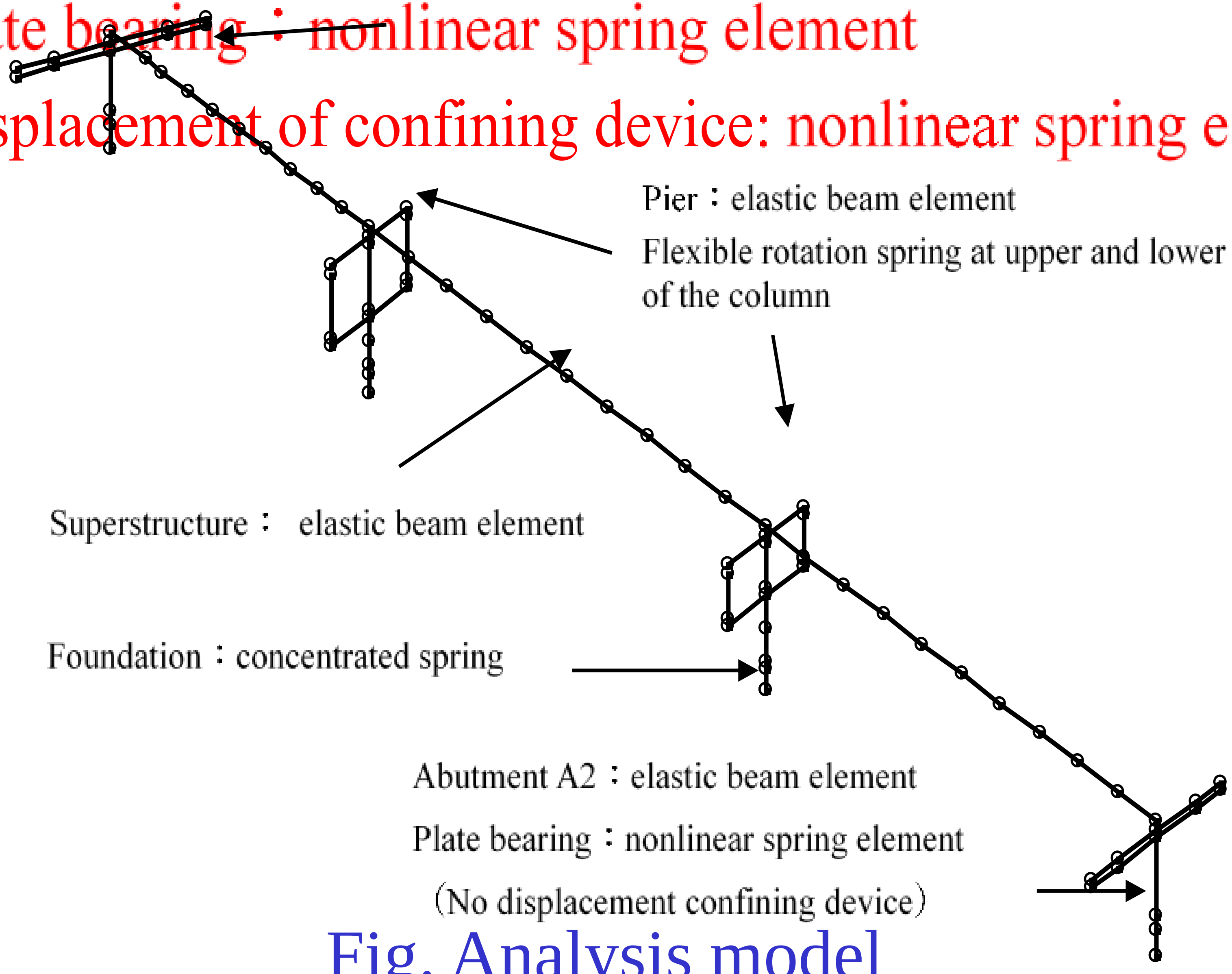


Fig. Analysis model

絶対加速度応答スペクトル

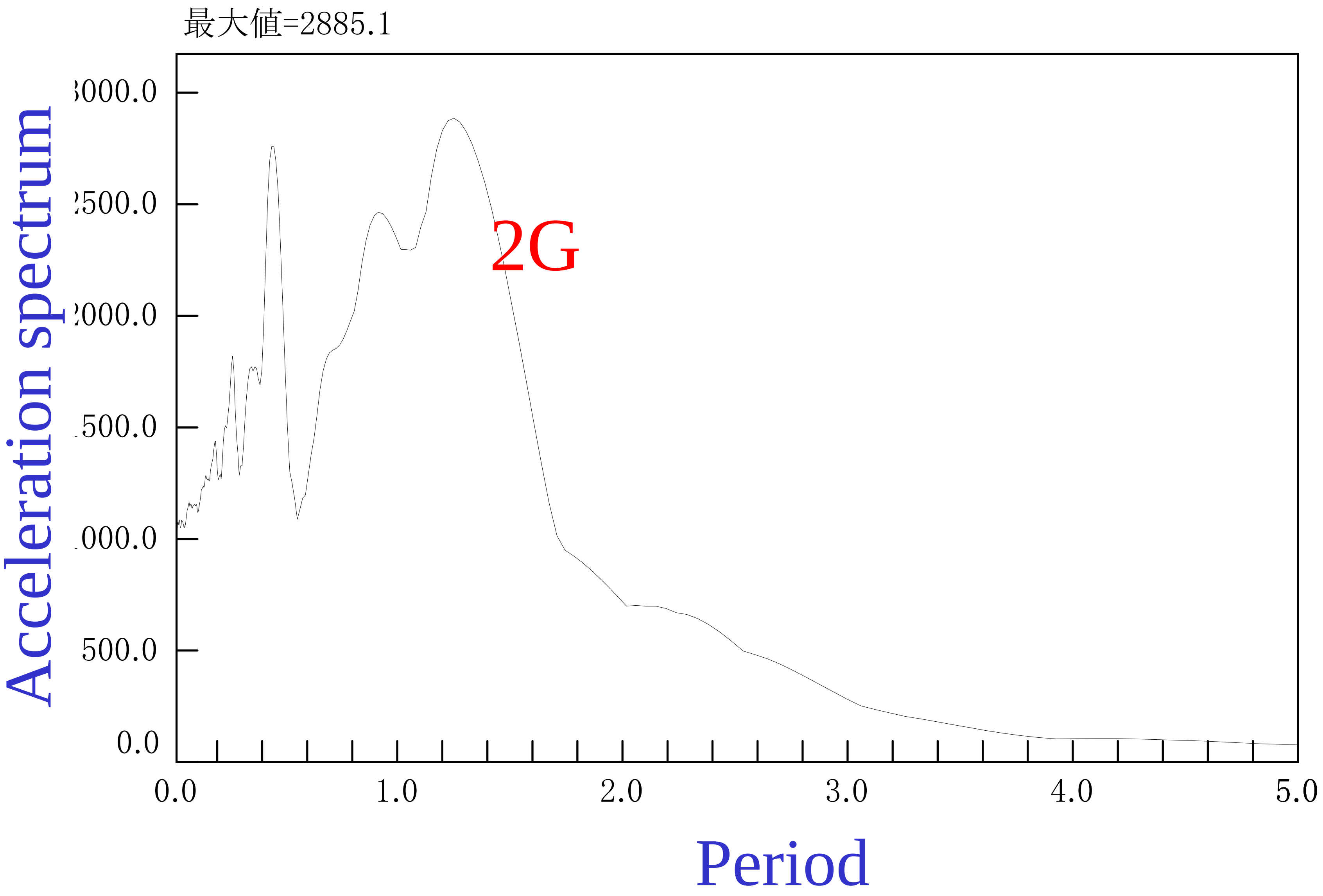


Fig. Acceleration spectrum observed in Mifune junction

Table 1 Analysis cases

Case	Strength of the bearing	Strength of the device	Remarks
Case 1	0.6 Rd	6.0 Rd	The design strength of the confining device is evaluated.
Case 2	1.8 Rd	6.0 Rd	The strengths of the bearing & device are evaluated most highly.
Case 3 (Basic case)	0.6 Rd	1.7 Rd	The case that shows the behavior closest to the actual behavior
Case 4	1.8 Rd	1.7 Rd	The actual strength of the bearing side block is evaluated.

Compare CASE3（actual behavior) with CASE2（reinforcing device).

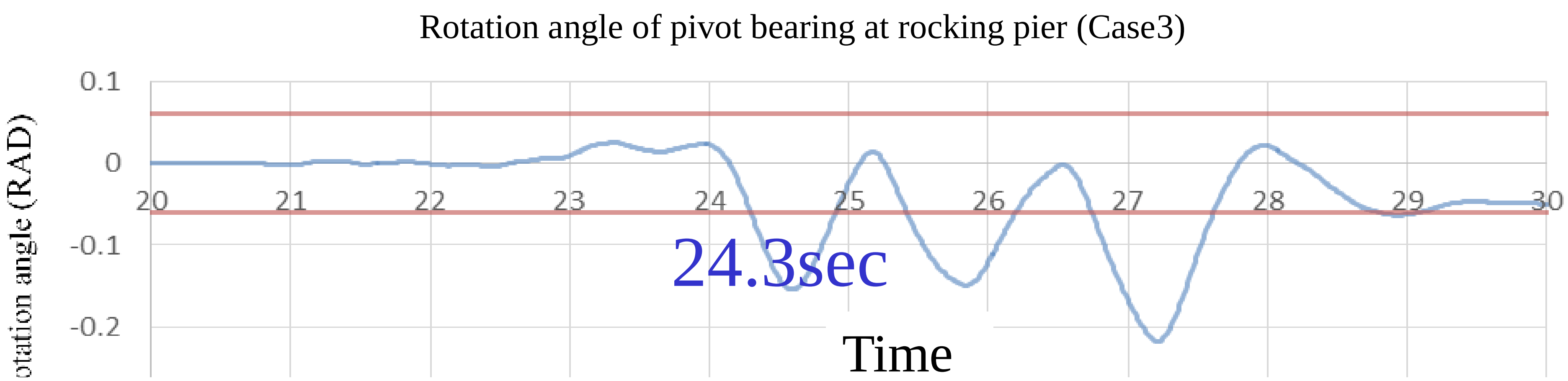


Fig. 6 Time history response of pivot bearing in Case3

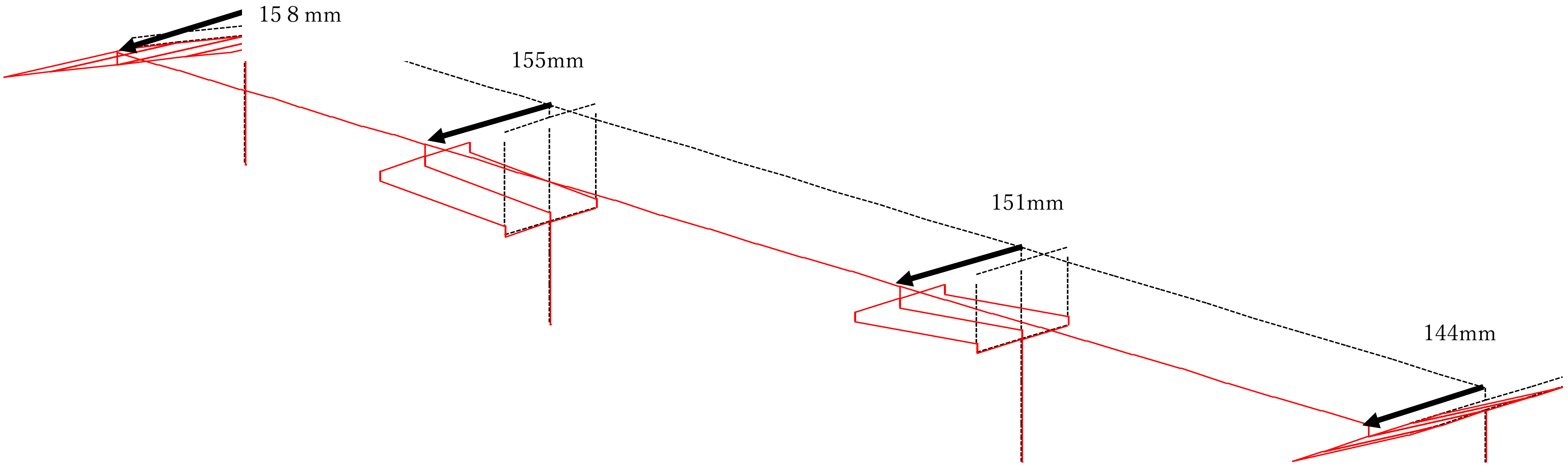
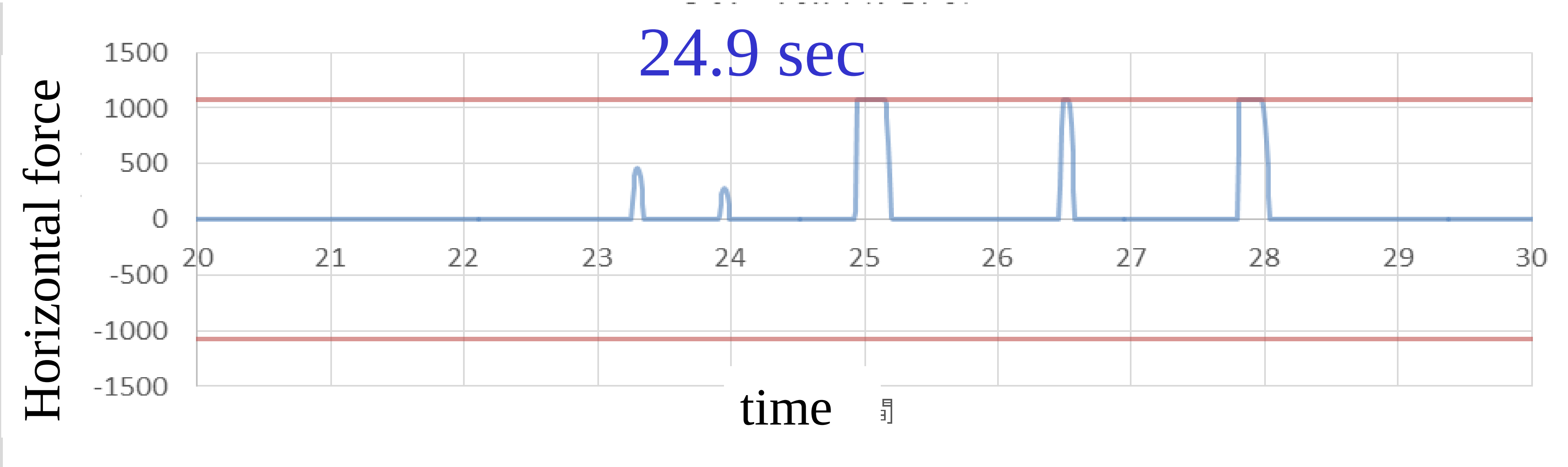


Fig. 7 Displacement of the bridge at 24.3Sec

In case3, rotation of pivot exceeds 0.06 rad at 24.3 sec.

Fig. Time history of confining device on the south side.



Failure order of CASE3：

③confining device（north side）[24.28]

④P2 pier pivot bearing [24.30]，bridge collapse.

Actual damage：No damage confining device at the south side.

Analysis results showed the same damage.

Case2（reiforcing）bearing1.8Rd,confining device 6.0Rd

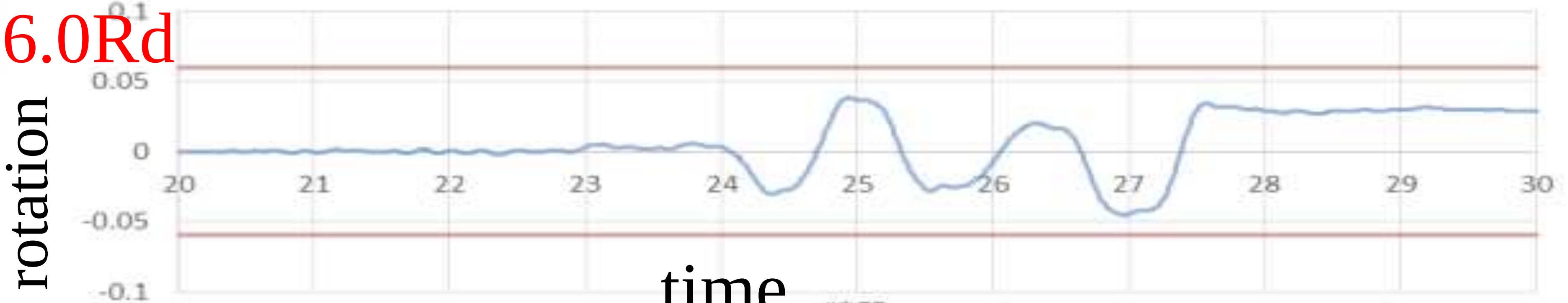


Fig. Time history response of pivot bearing at P2 (CASE2)

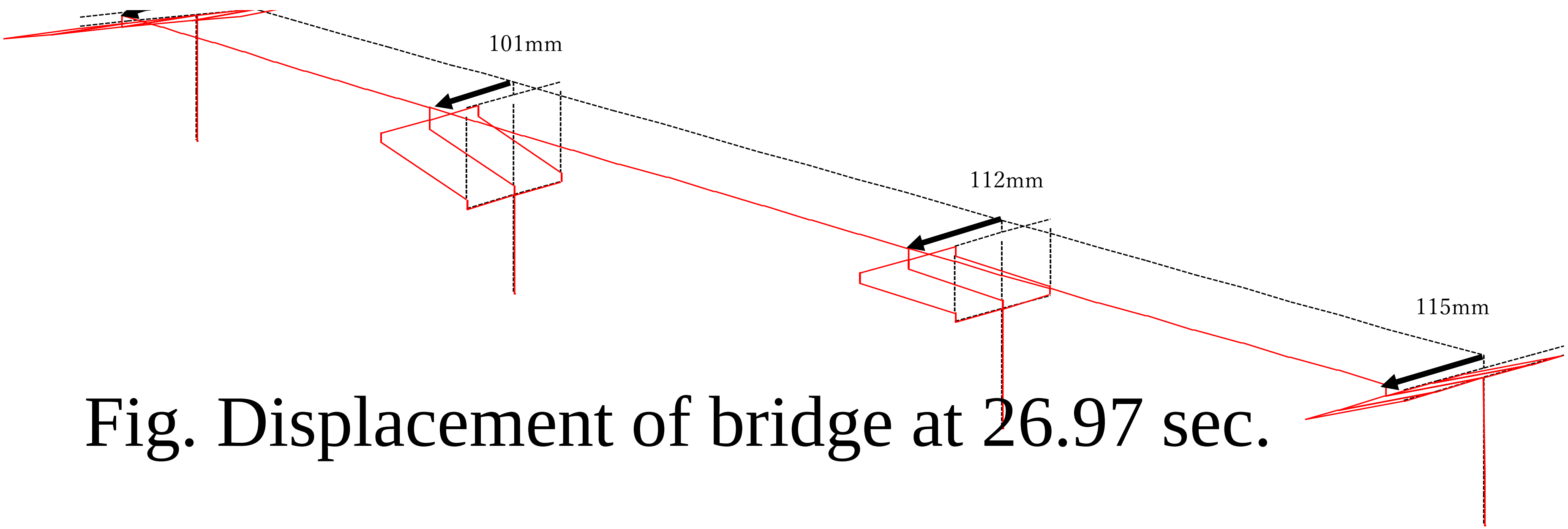


Fig. Displacement of bridge at 26.97 sec.

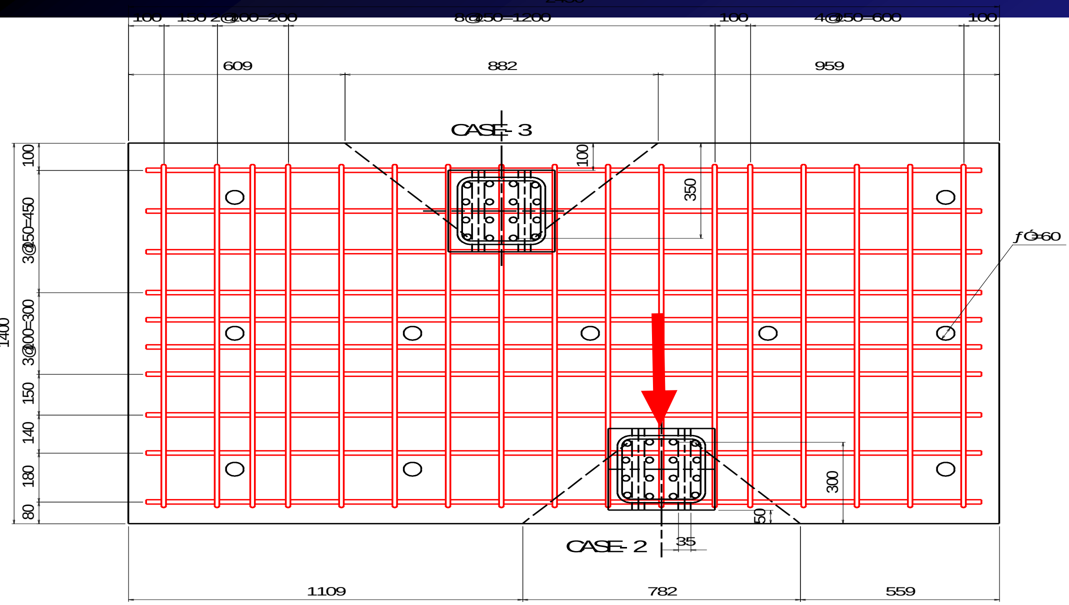
In case2, rotation is within 0.06rad.

Conclusions：

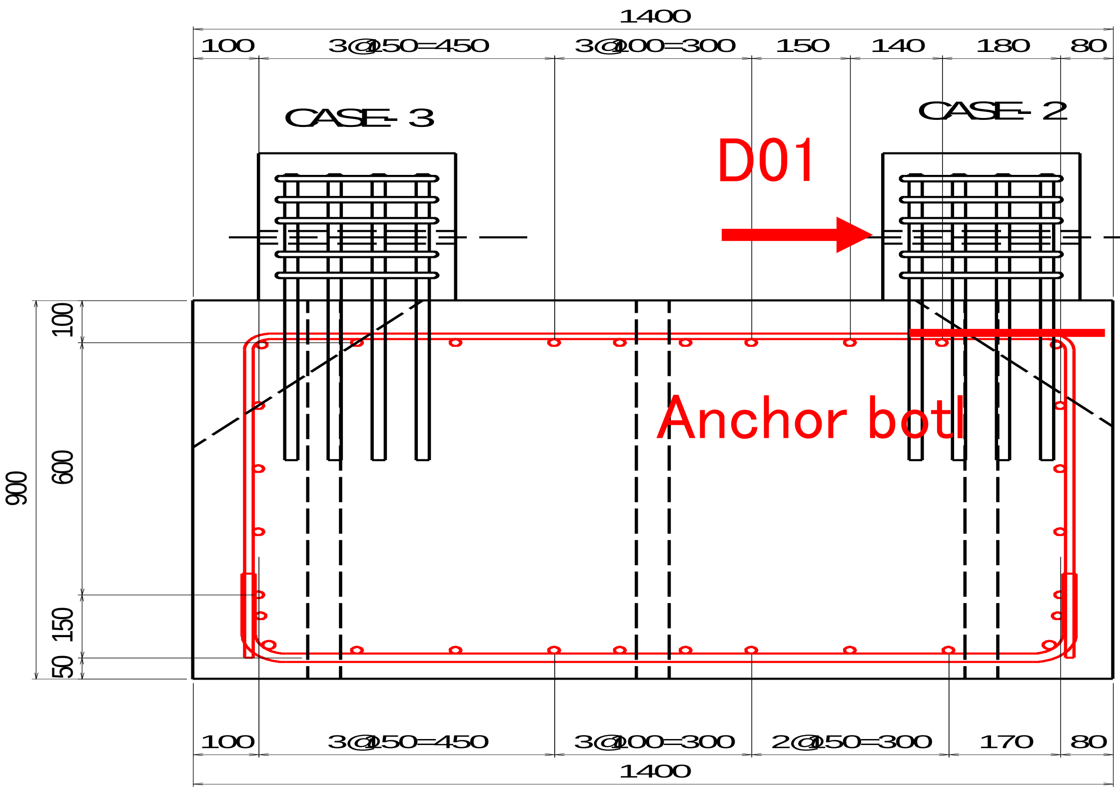
1. The damage was caused not only by the rotation of the superstructure but also by the movement of the superstructure to the perpendicular direction due to seismic force.

2. As the improvement measures, We propose to increase the punching shear resistance of a confining device.

I. On going research



1. To investigate the punching shear resistance of confining device



2. Full scale punching shear test was conducted.

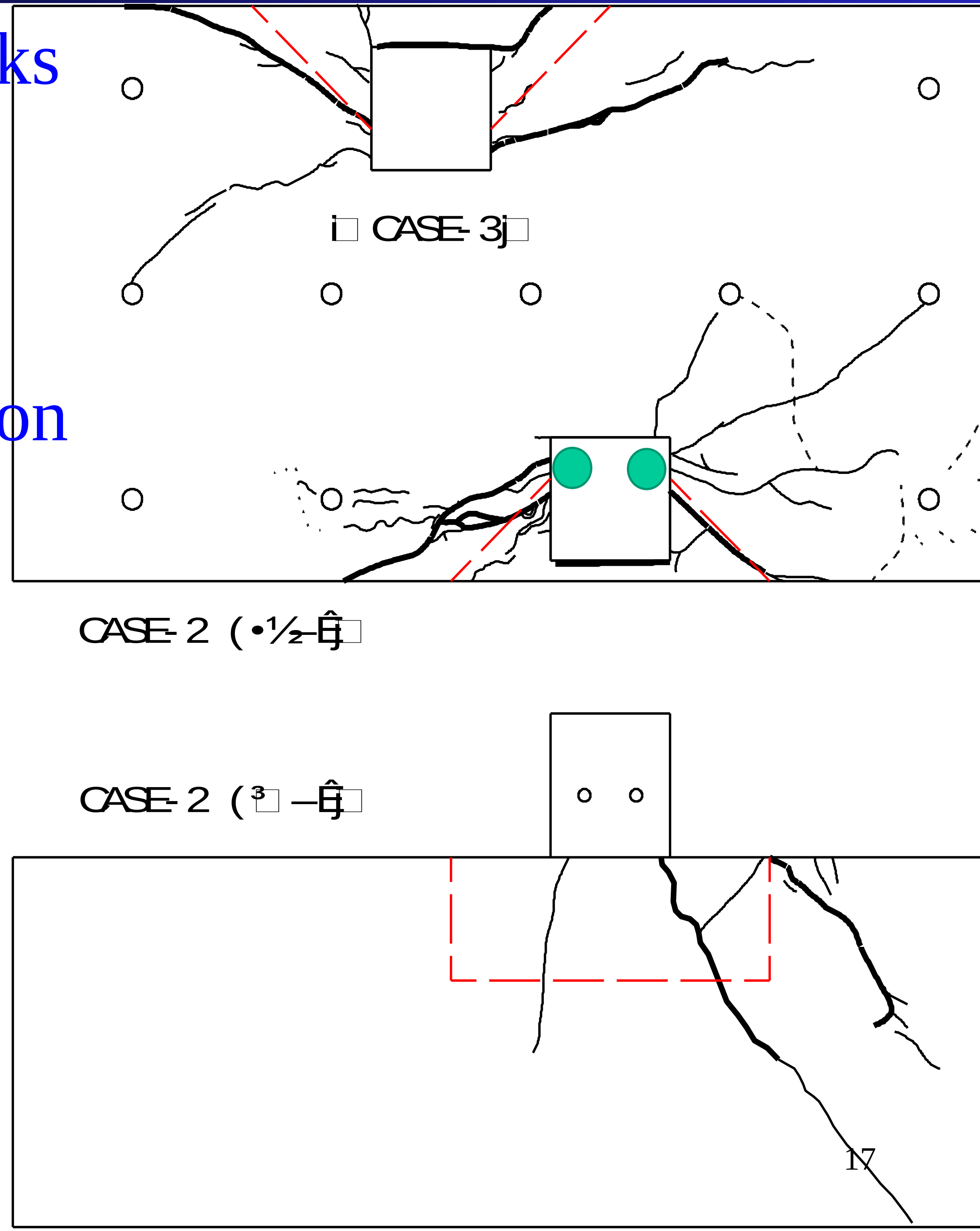
3. Monotolic load is applied.

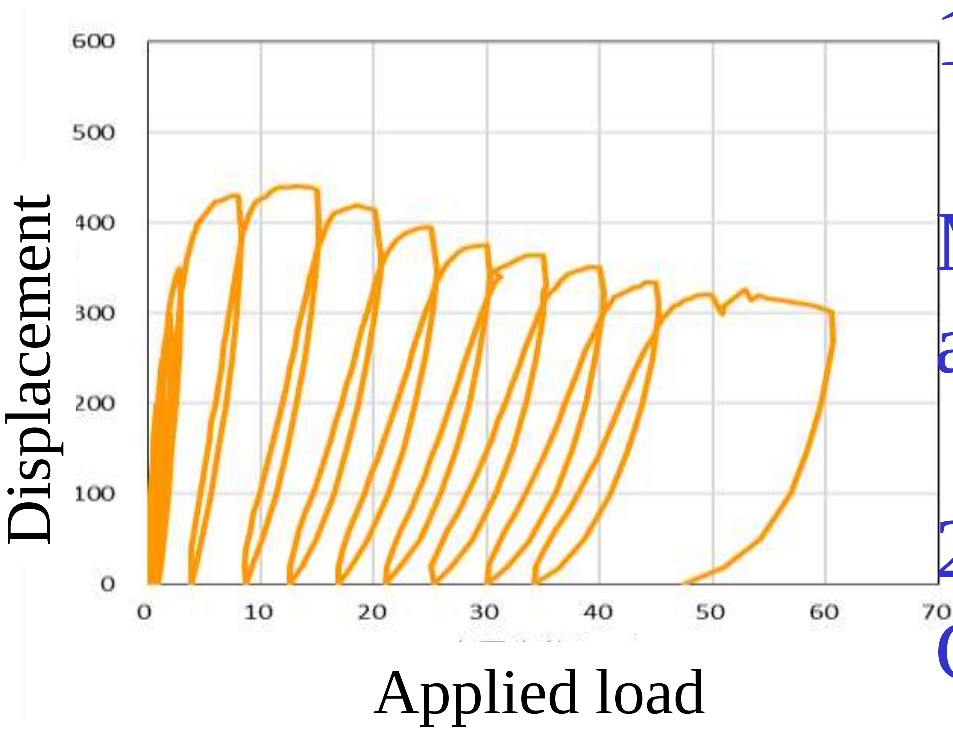

CASE2

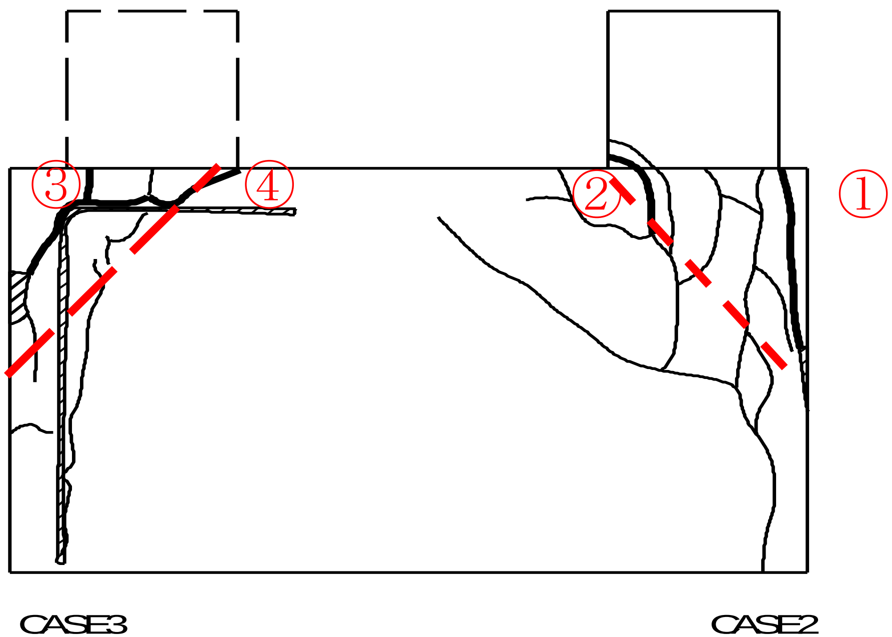
1.Fig. shows the cracks at the maximum load

2.Cracks starts from the anchor bolt position of cross section.

3.Cracking angle is 45°







1.Fig. Load-displacement

Maximum load is reached at 10mm displacement.

2.Fig. Ultimate Cracks at Cross section

Cracks starts from the anchor bolt position.

3.Results shows the good agreement with Road Specifications.