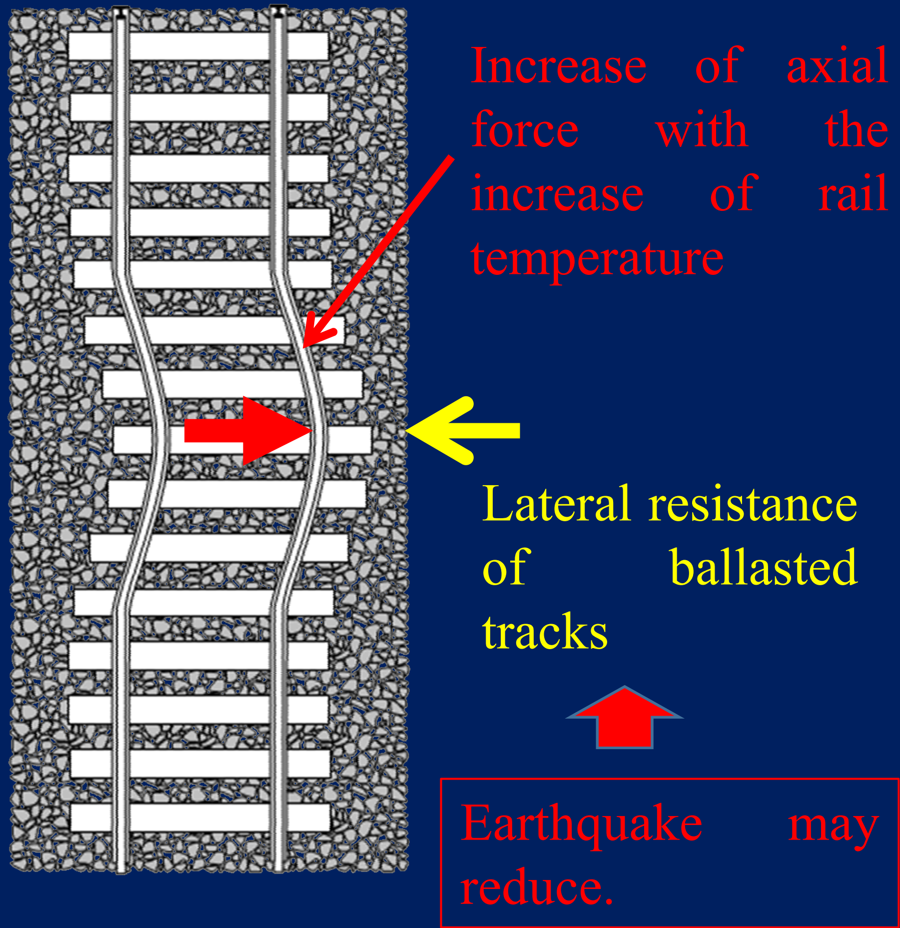
Lateral resistance characteristics of ballasted tracks subjected to angular folding at boundaries between structures

Yokohama National University Kimitoshi Hayano
Railway Technical Research Institute Takahisa Nakamura
Railway Technical Research Institute Yoshitsugu Momoya

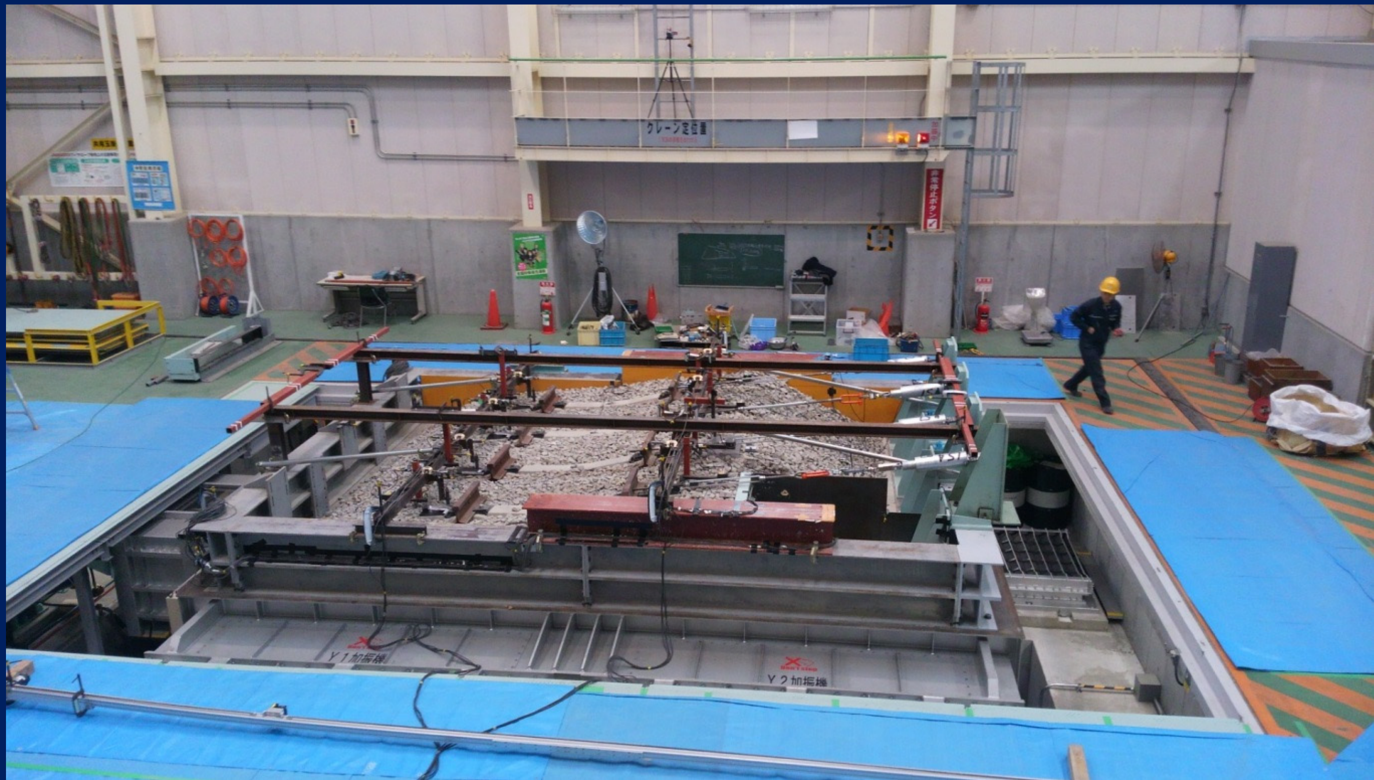
Background

Damage observed after an earthquake
(Momoya et al. 2013)



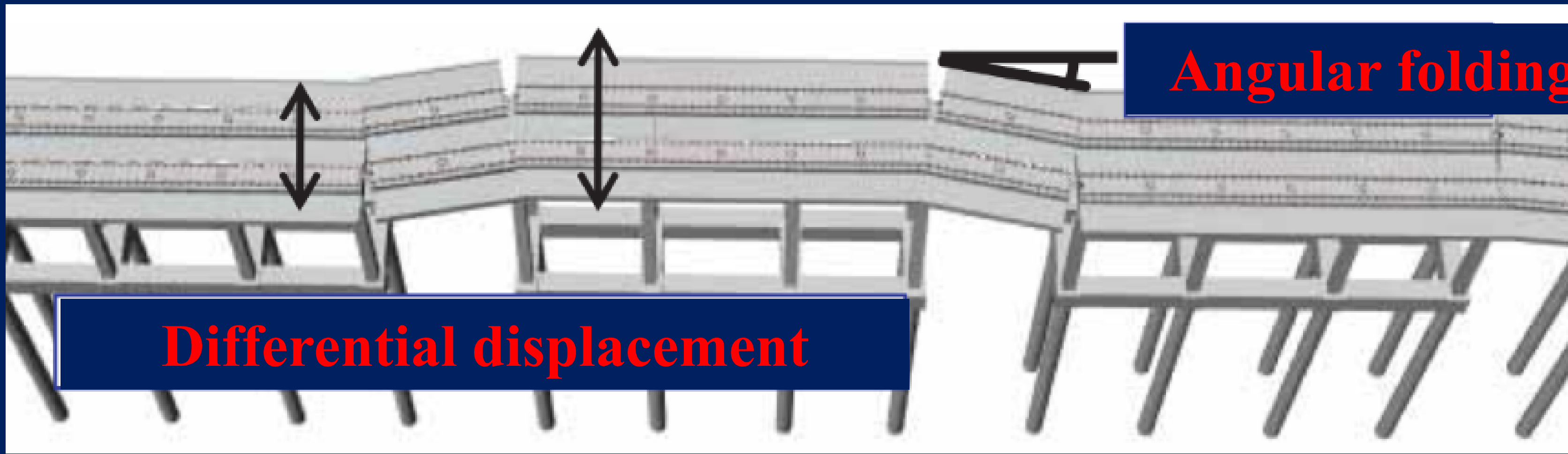
Lateral resistance characteristics of ballasted tracks subjected to earthquakes should be clarified so that appropriate countermeasures can be implemented.

Nakamura et al. (2014) conducted a series of shaking table tests on full-scale ballasted tracks. They found that lateral resistance was reduced during and after seismic motions.



Shaking table tests on a full-scale ballasted track
(Nakamura et al. 2014)

Railway tracks at structure boundaries have other problems.



Elevated railway bridges subjected to earthquakes
(Takahashi et al., 2008)

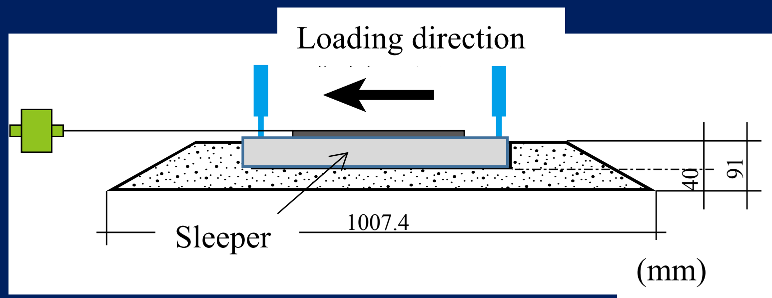
In addition to seismic vibration, local differential displacement or angular folding at structure boundaries may affect the lateral resistance of ballasted tracks.

Objective

➡ To investigate lateral resistance characteristics of ballasted tracks subjected to angular folding at boundaries between structures.

Methodology

➡ To conduct sleeper pull-out tests on small scale (1/5 scale) models.

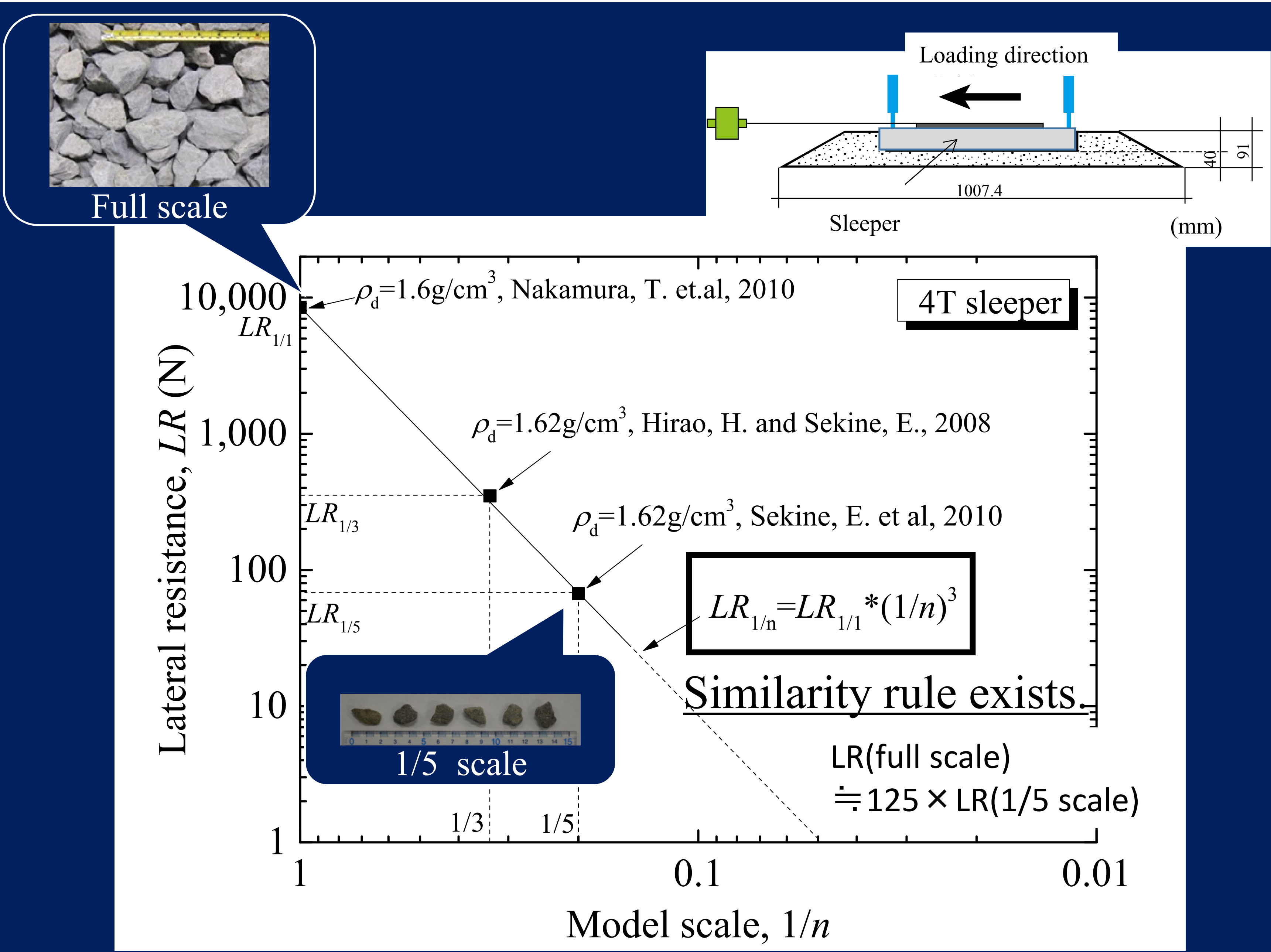


Track panel pull-out test on a 1/5 scale model

Full scale model tests

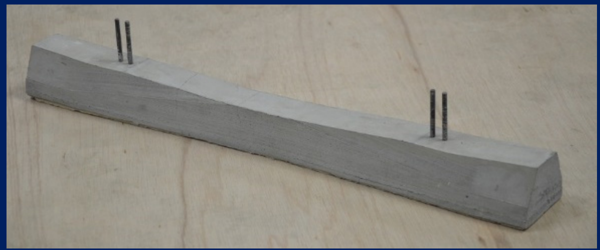
As it takes large efforts to conduct full scale tests, small scale (1/5 scale) tests were conducted in this study.

Small scale (1/5 scale) model tests



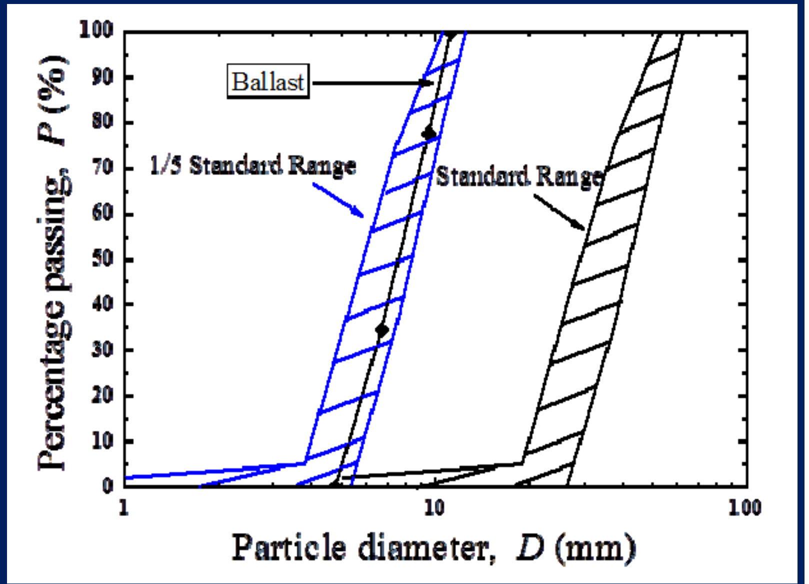
Effects of model scale on the lateral resistance
(from a single sleeper pull-out tests)

Model test method

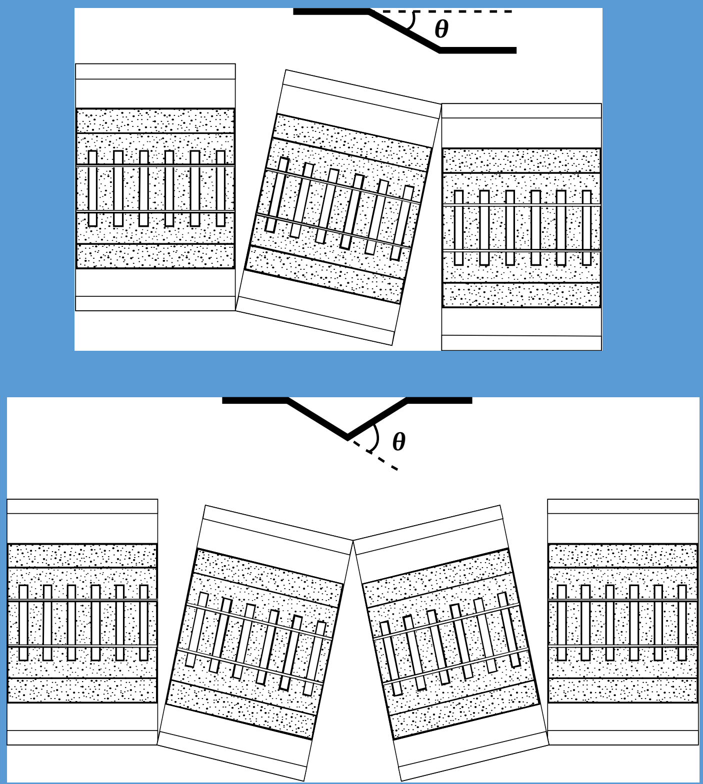


3H sleeper (1/5 scale)
(Mainly used for Shinkansen)

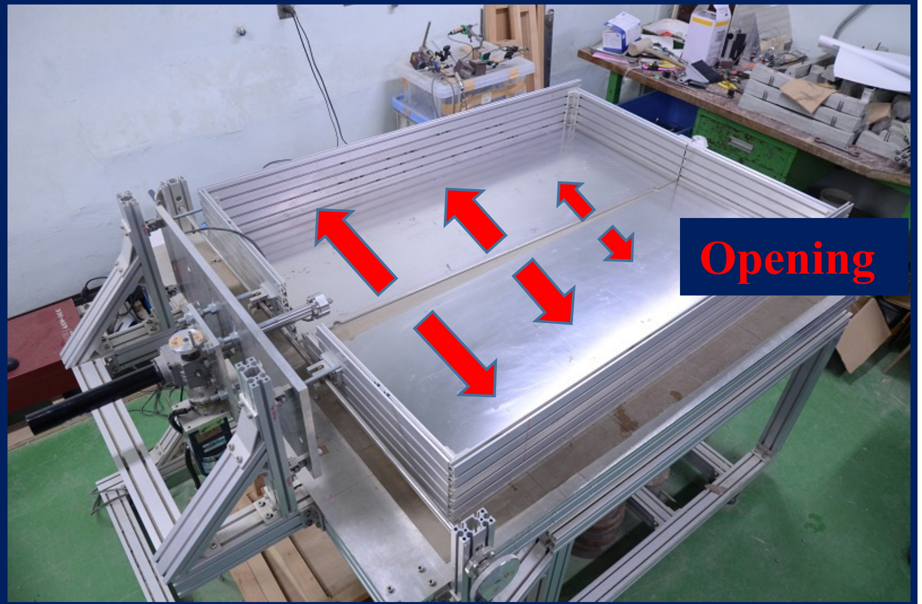
1/5 scale beds

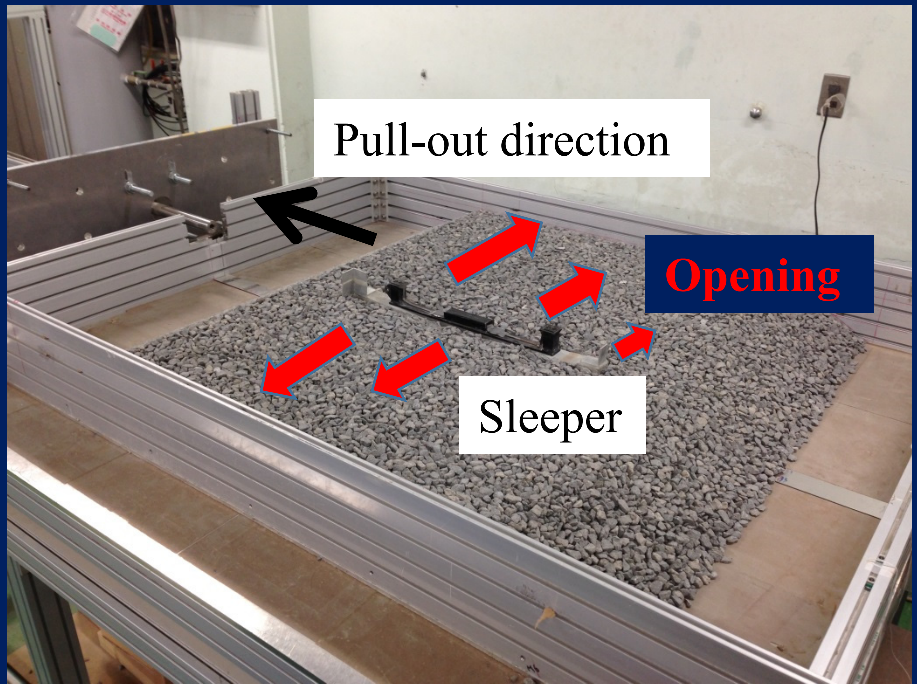


Crushed stones
(Andesite)

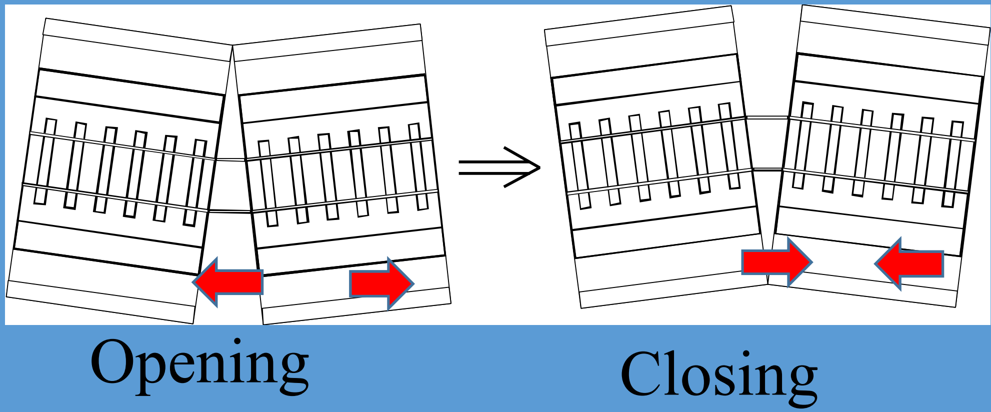


Railway tracks subjected to angular folding

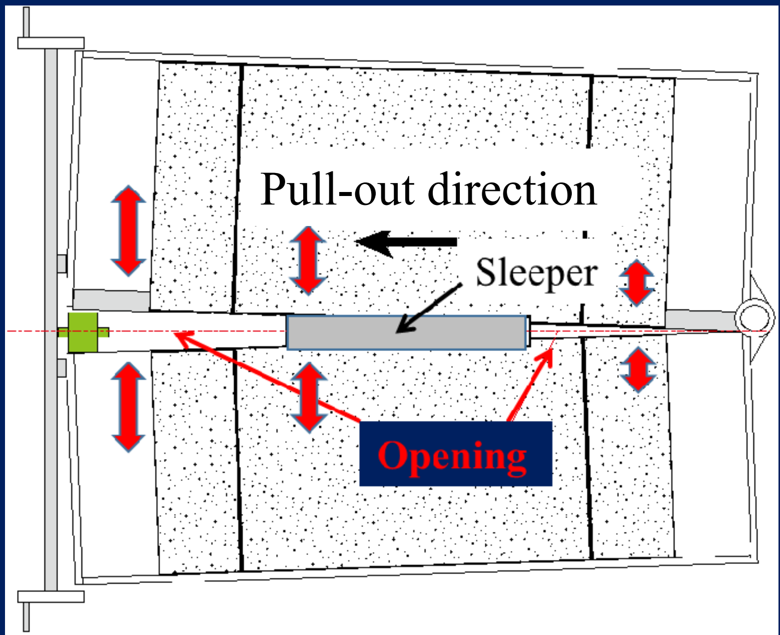


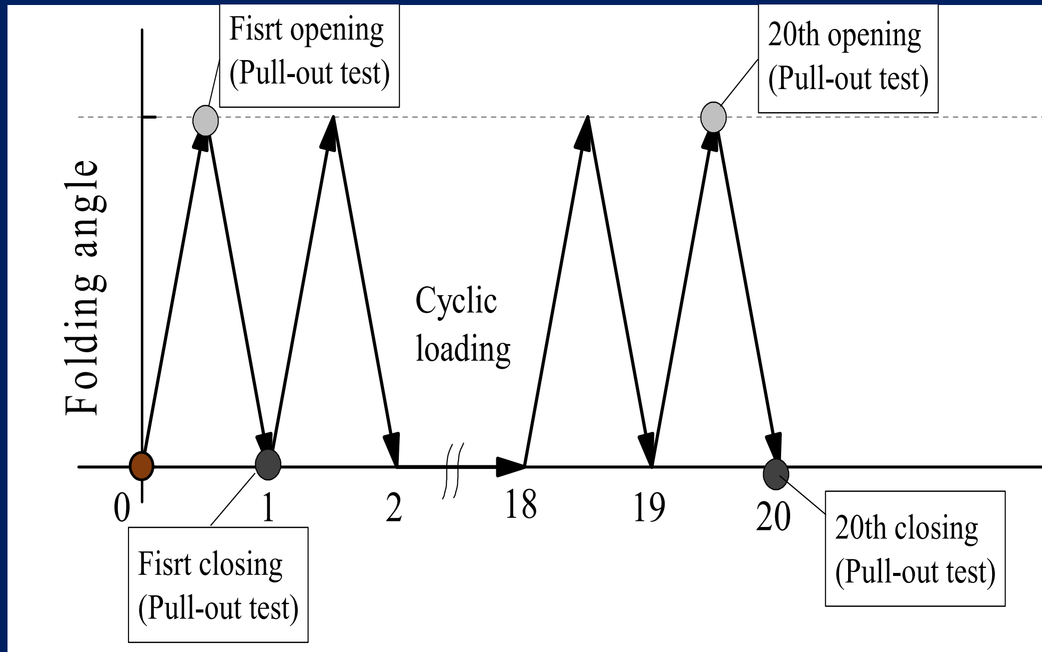


Physical modeling of angular folding in model test



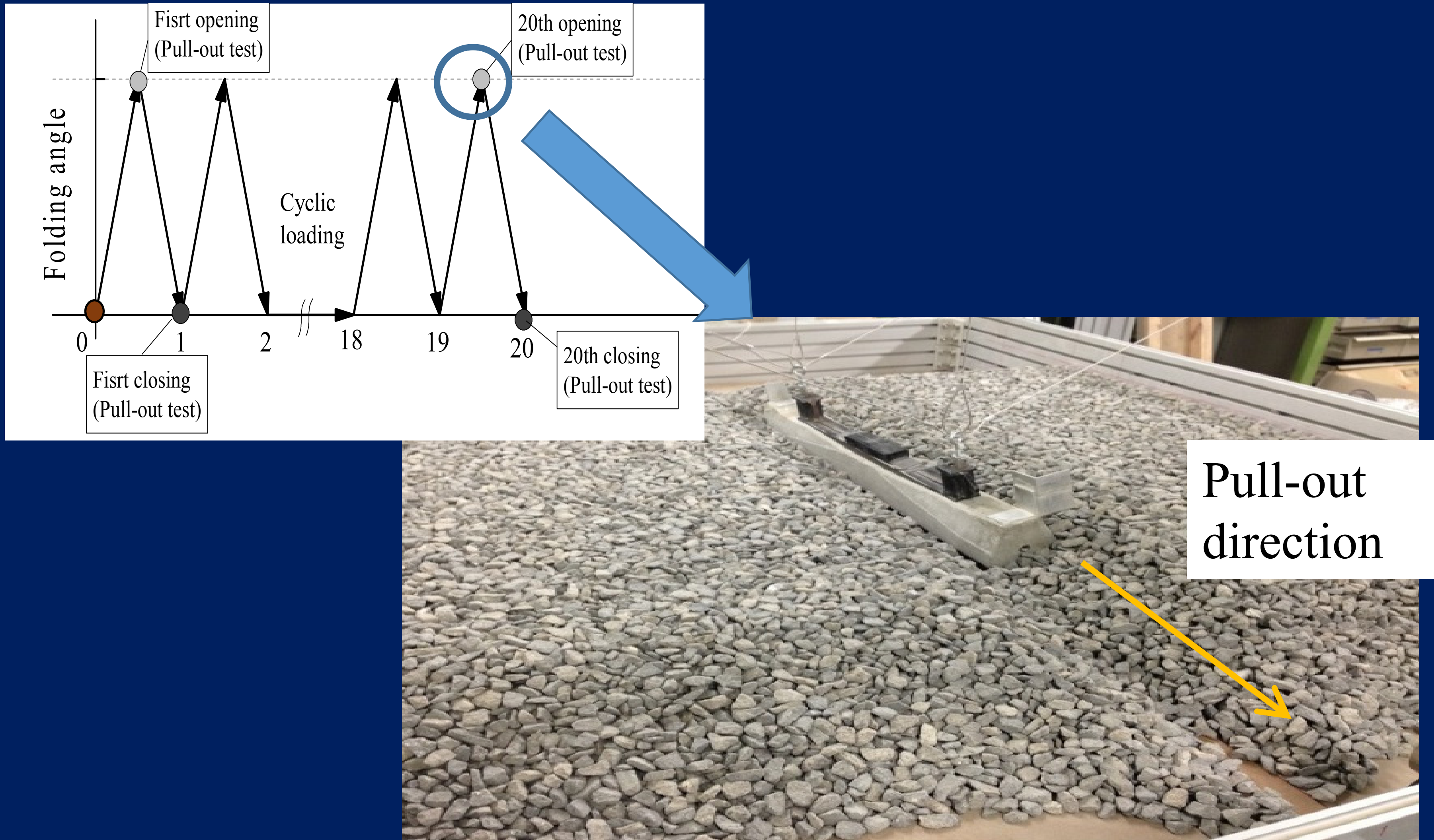
Angular folding is repeated during an earthquake. Opening or closing situation can be cyclically expected at boundaries.



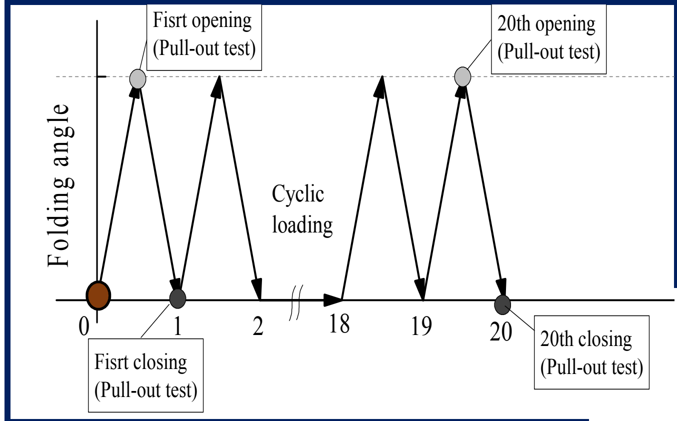


Physical modeling of cyclic loading (folding) in model test and sleeper pull-out tests under opening or closing situation

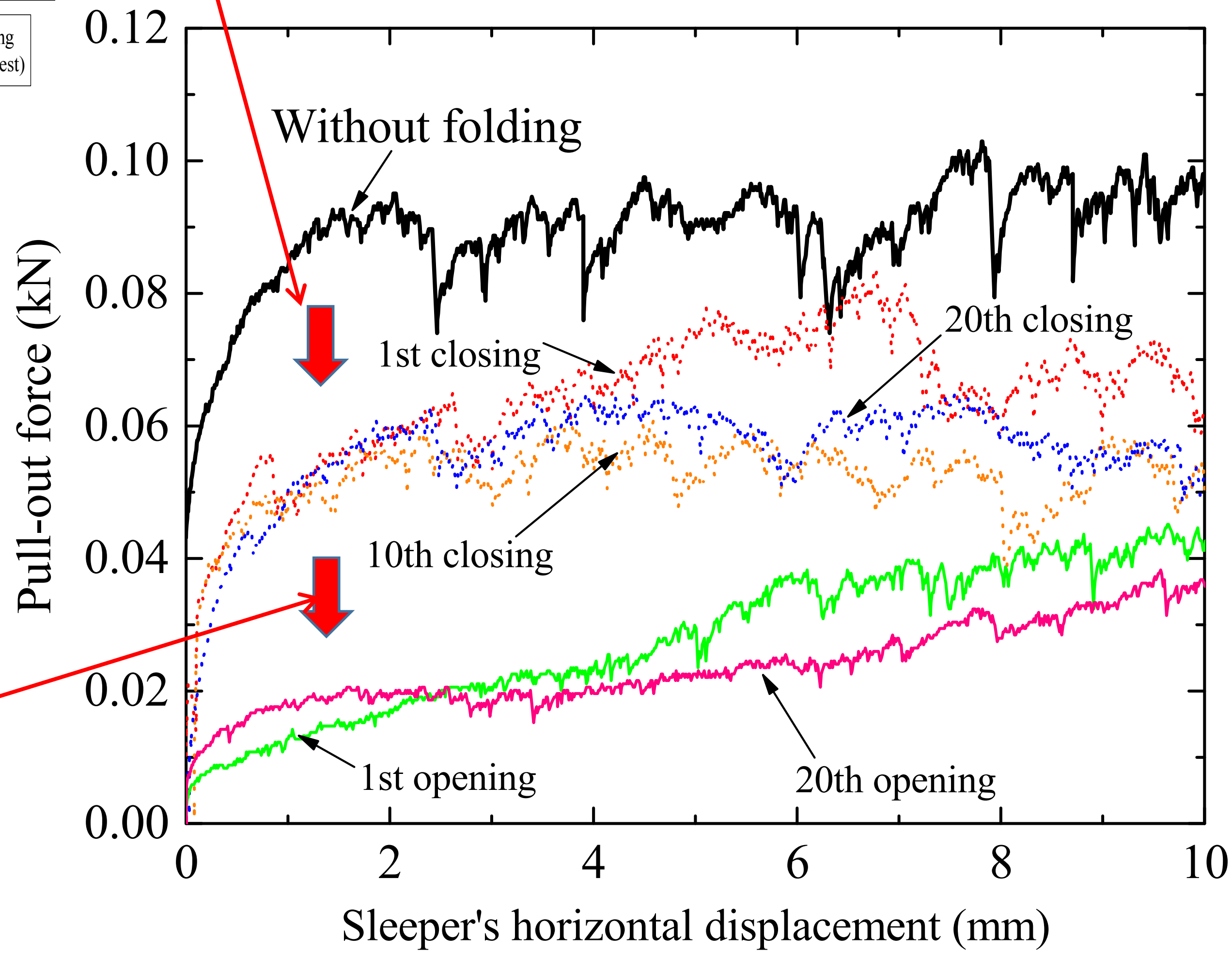
Single sleeper pull-out test



Single sleeper pull-out test at 20th opening

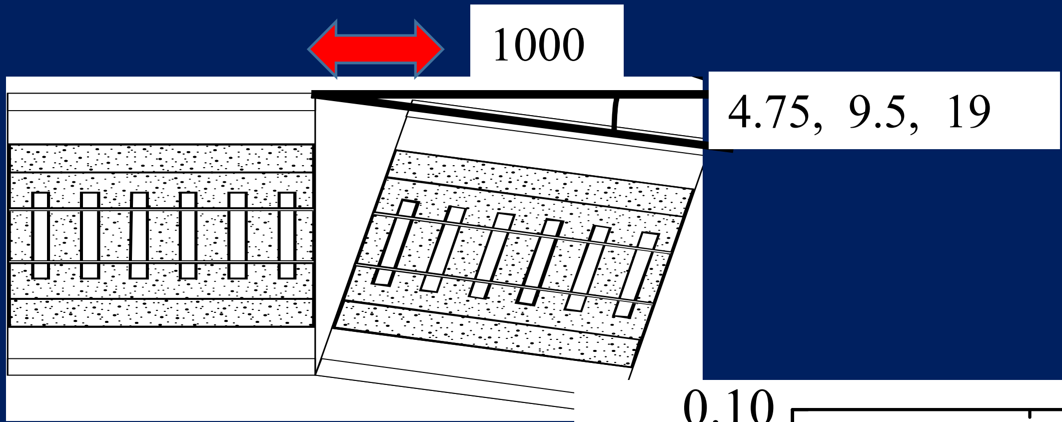


Angular folding experience reduced the lateral resistance.

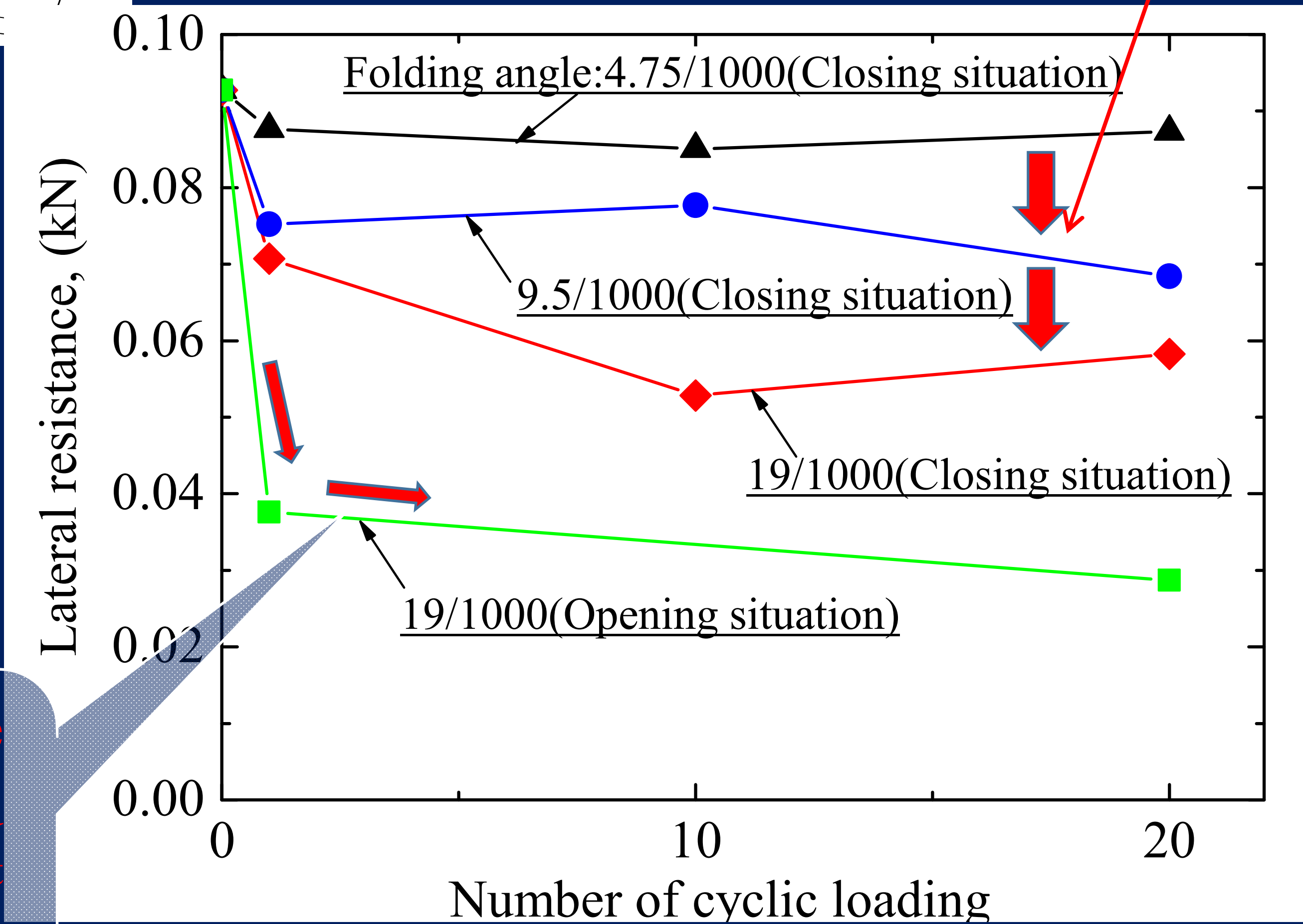


The lateral resistance was drastically reduced under the opening situation.

Single sleeper pull-out test results(folding angle: 19/1000)



With increase of the folding angle, the lateral resistance was decreased.

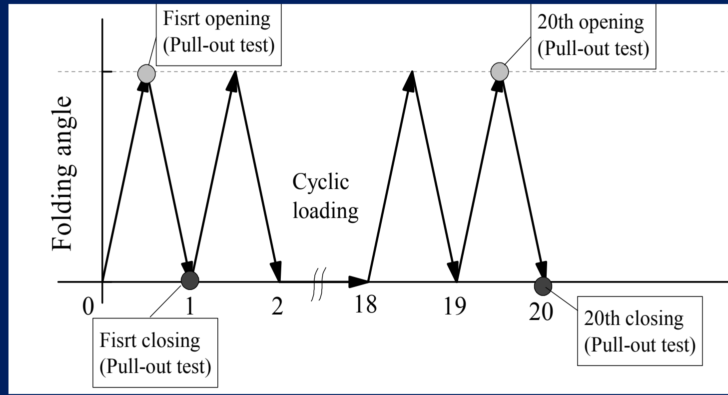


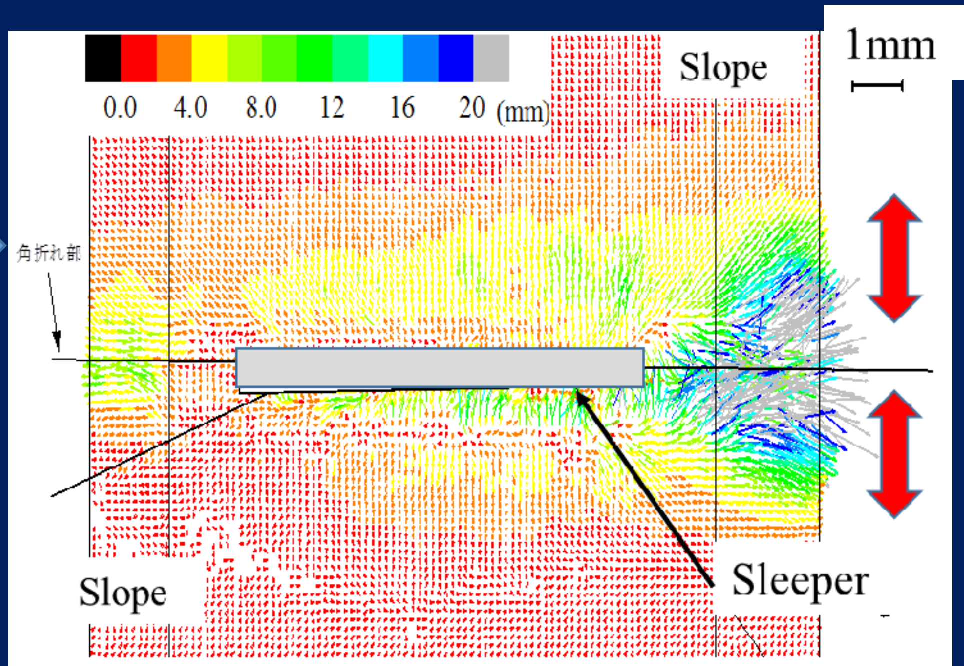
Lateral resistance might be reduced little beyond 1st loading (folding).

Single sleeper pull-out test results

Before the start of 1st folding

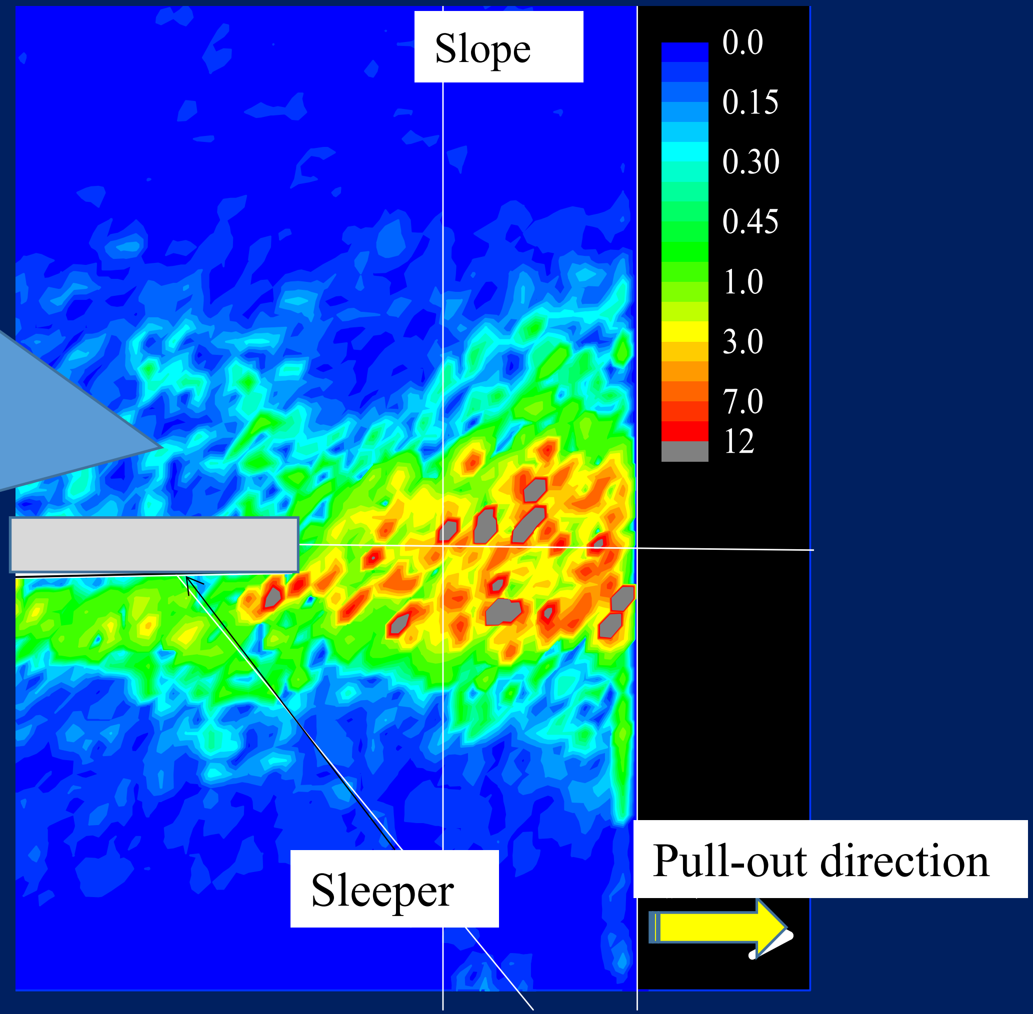
After the 20th cyclic loading (folding)



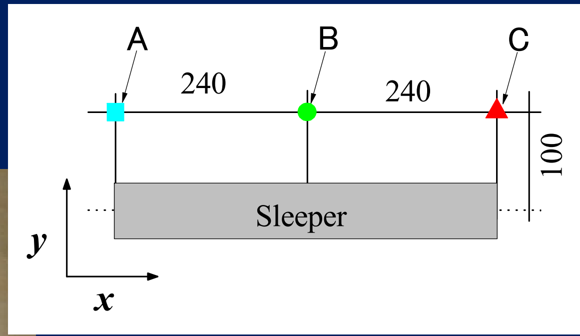


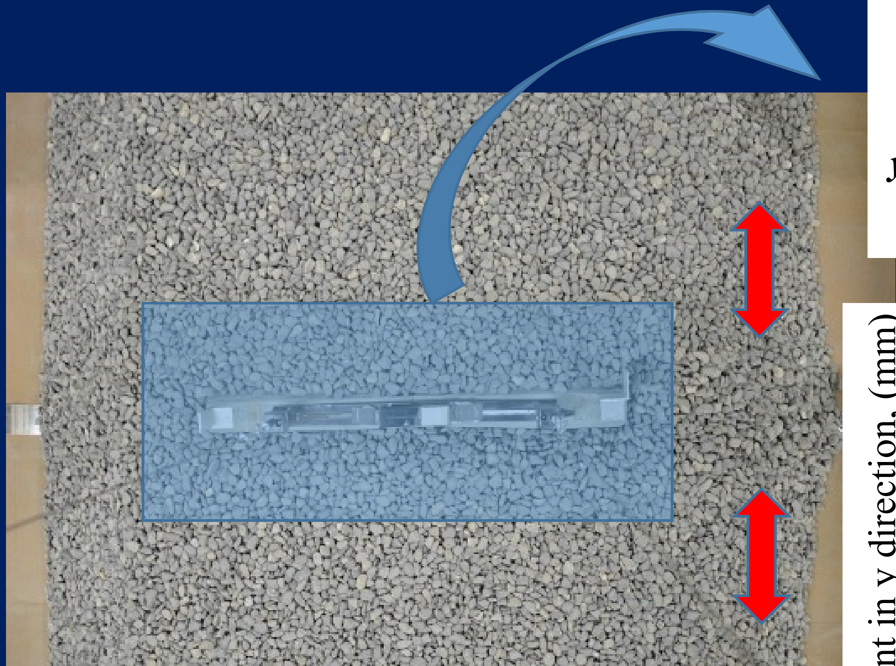
Accumulated displacements after the 20th cyclic loading (folding) from PIV

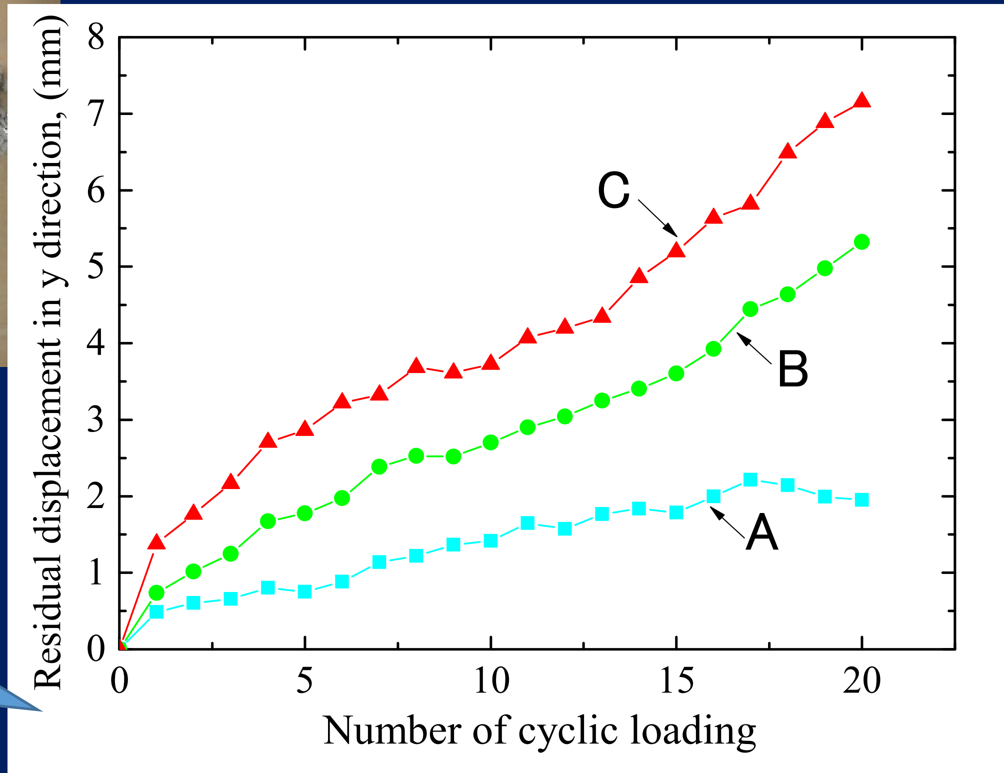
Shear strain was significantly developed near the sleeper end before pull-out loading.
The fact indicates that the bottom end resistance could be reduced before the start of pull-out tests.



Maximum shear strain distribution near the sleeper end after the 20th cyclic loading (folding) from PIV



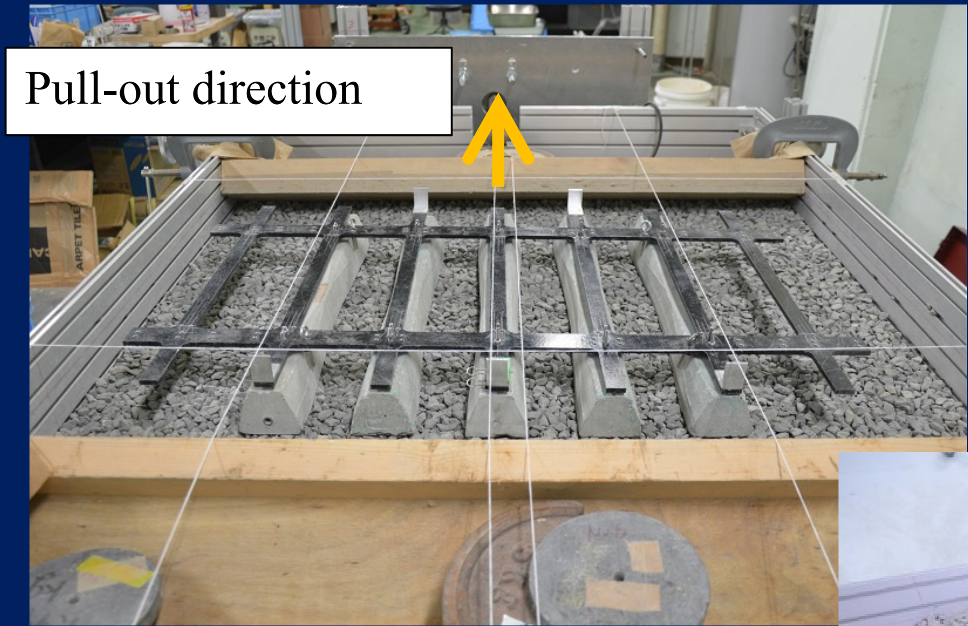


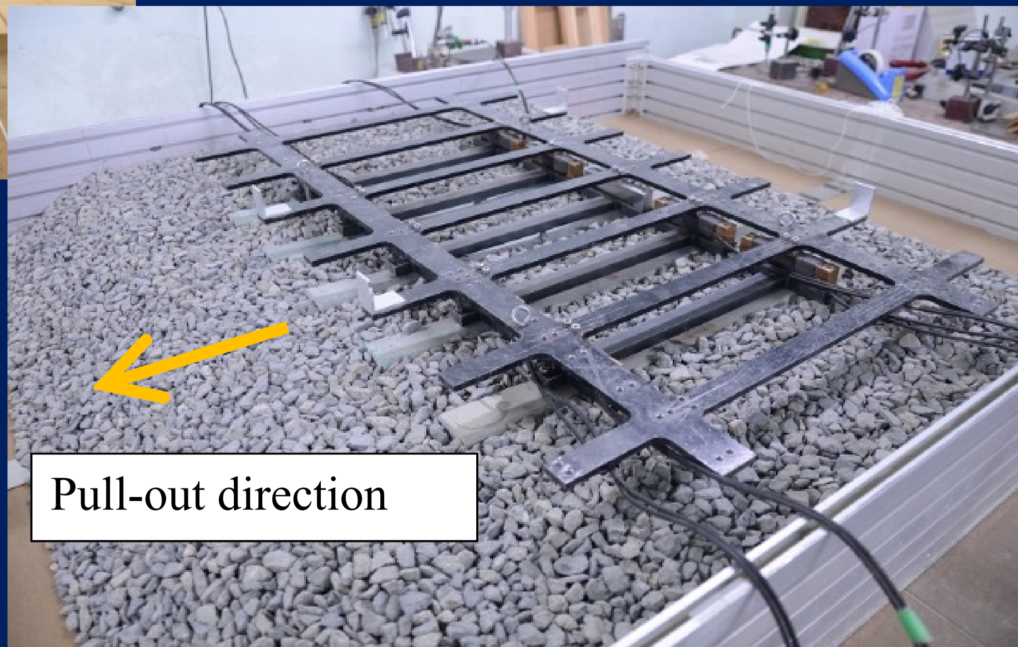


Ballasts moved away from the sleeper side. The fact indicates that the side resistance could be reduced.

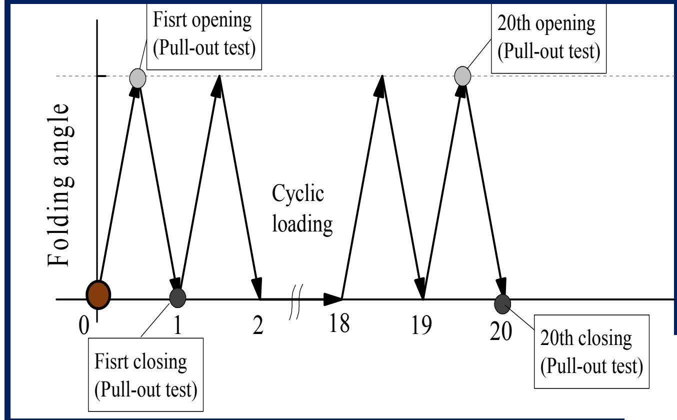
Residual displacements in y direction at points A, B and C near the sleeper side from PIV

Track panel pull-out test

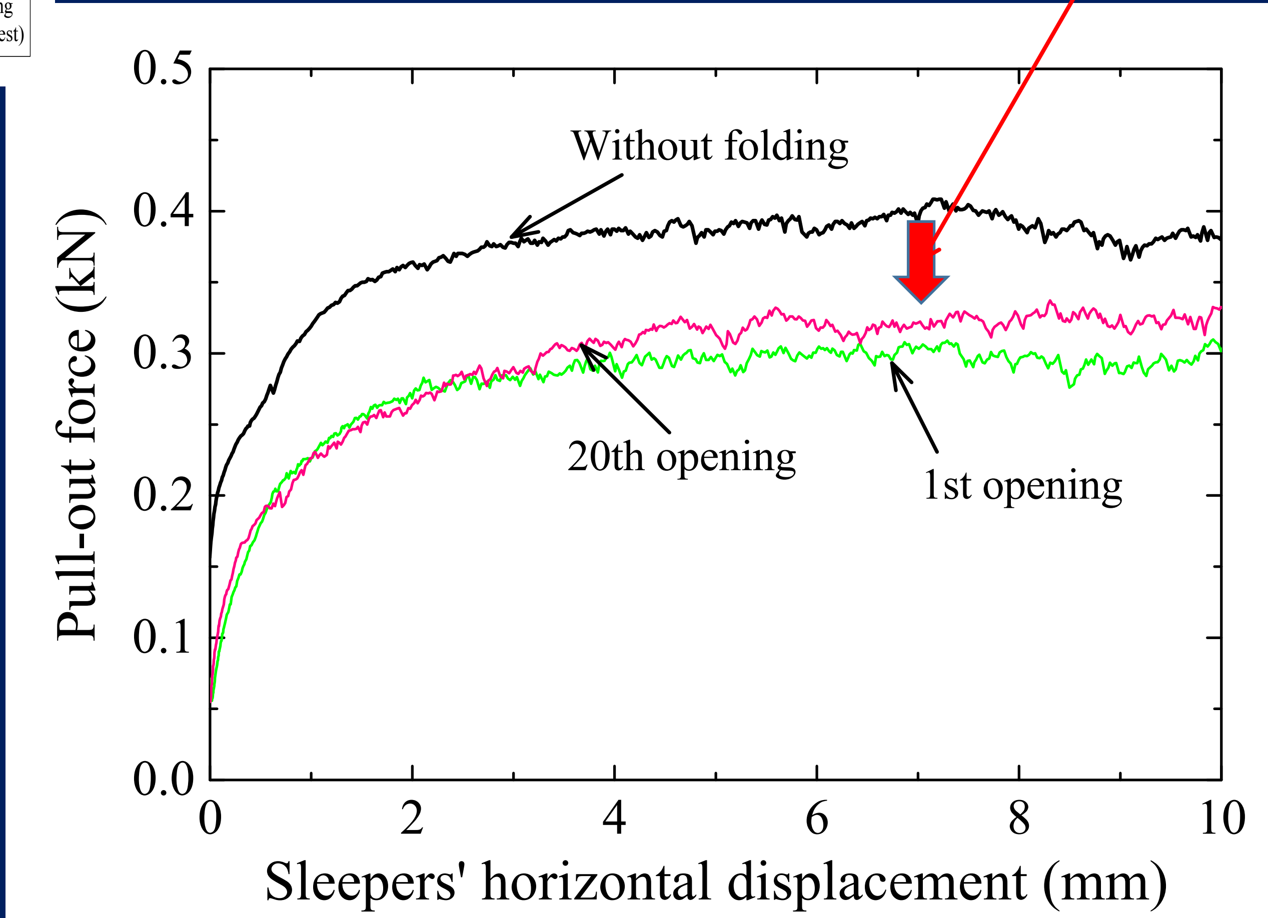




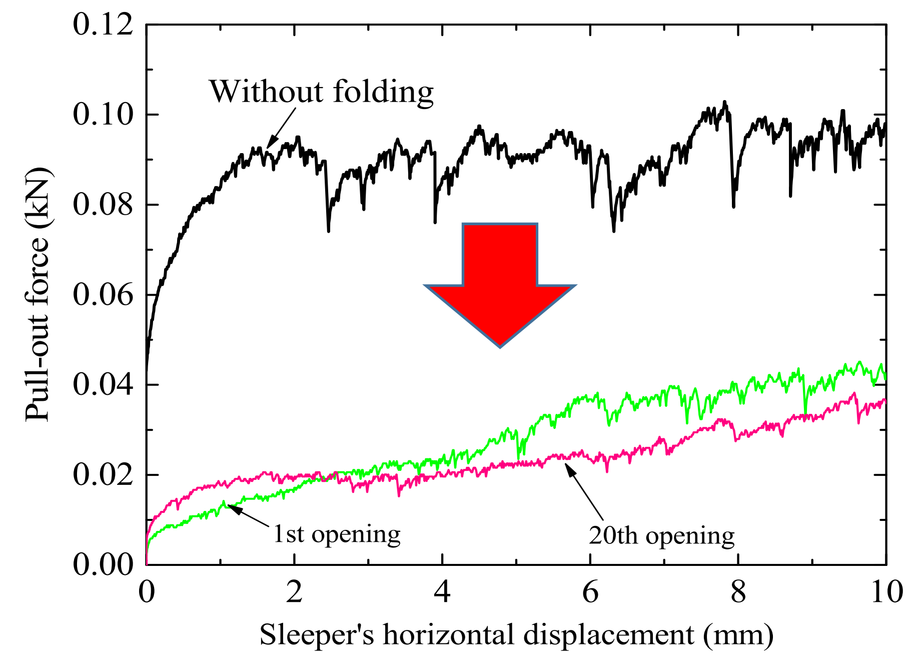
Track panel pull-out tests with 5 sleepers

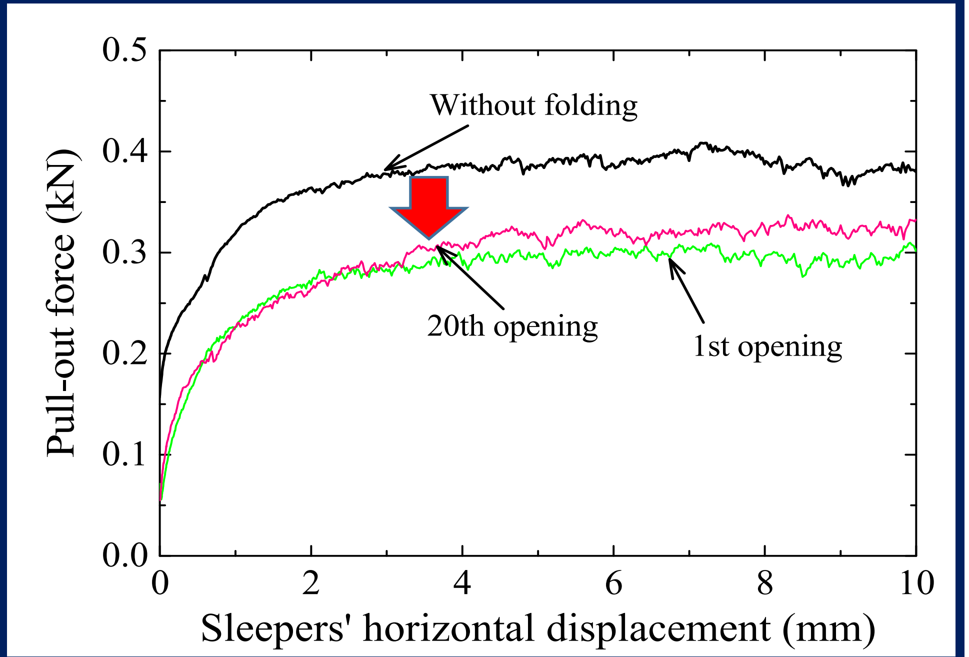


Angular folding experience reduced the lateral resistance.



Track panel pull-out test results(folding angle: 19/1000)



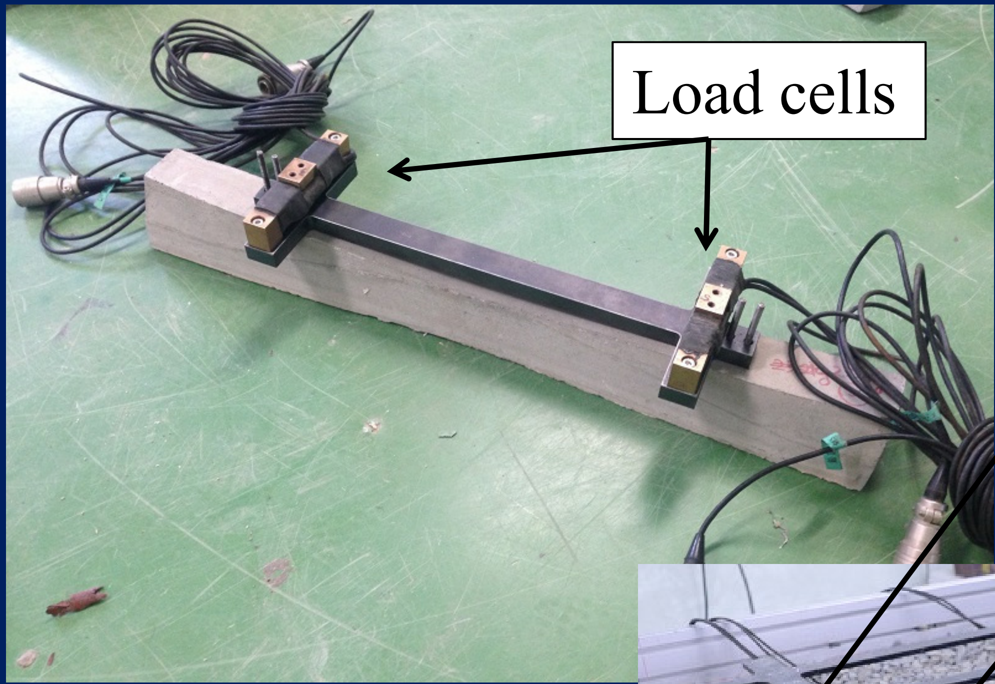


Single sleeper pull-out test results

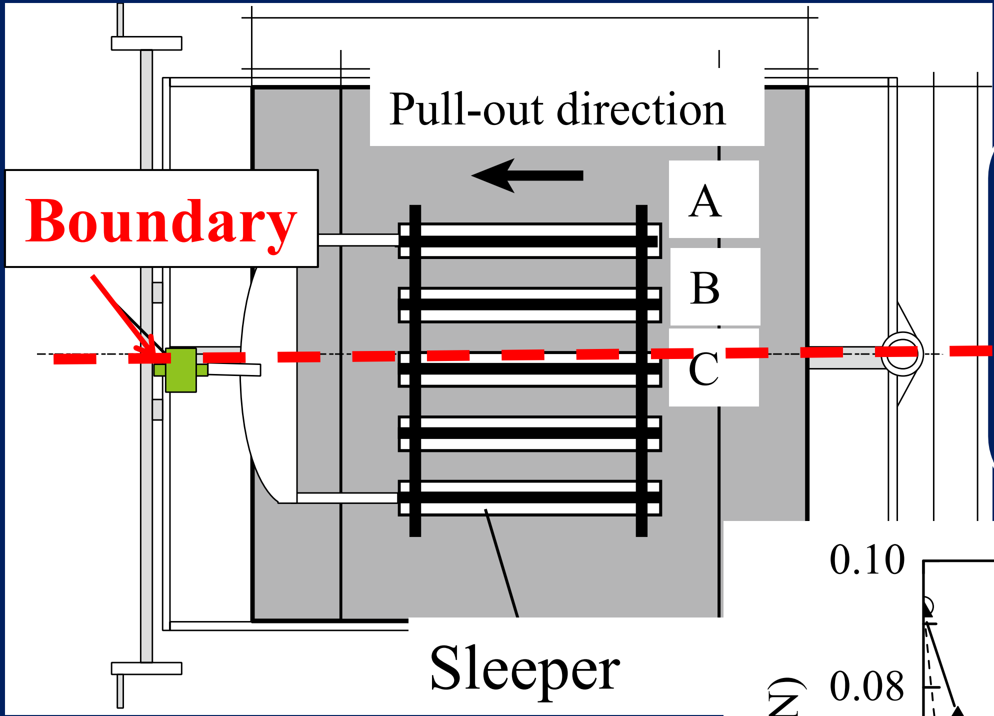
Track panel pull-out test results

(folding angle: 19/1000)

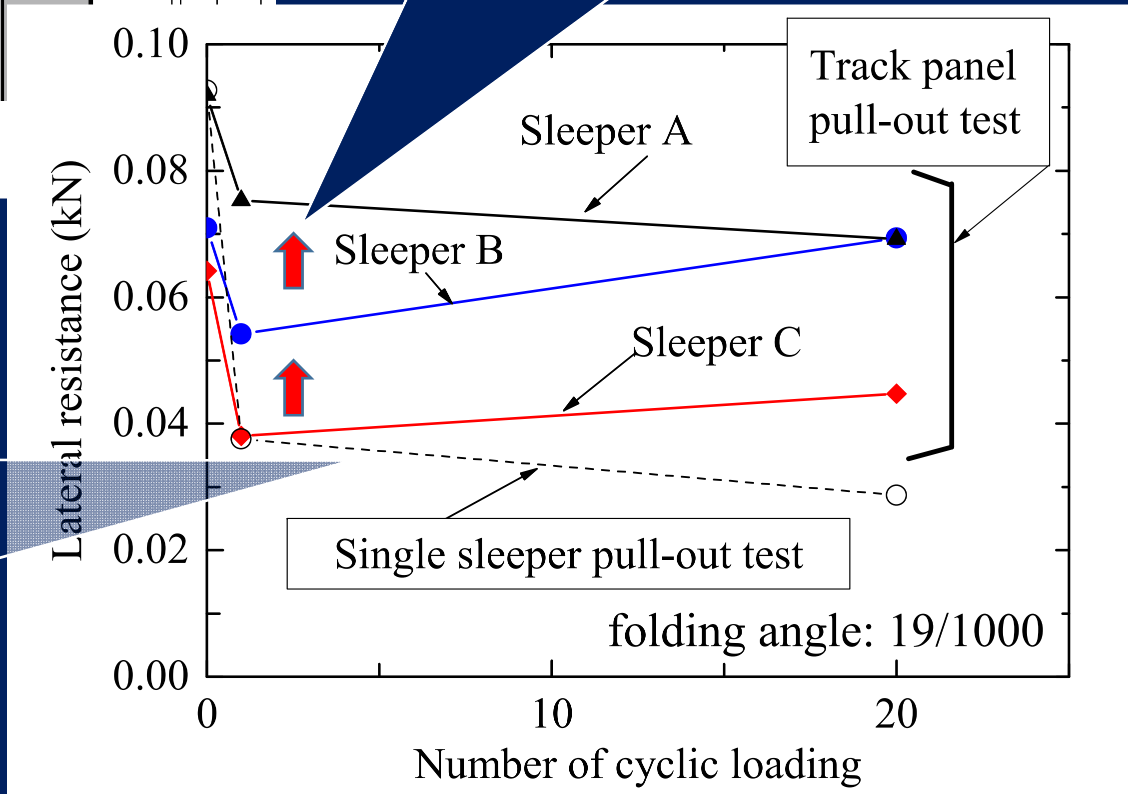
Reduction of lateral resistance was 60 -70 % in case of single sleeper pull-out tests while 20 – 25 % in case of track panel pull-out tests.



Load cells were installed on the sleepers so that lateral resistance of each sleeper could be measured in the track panel pull-out tests.

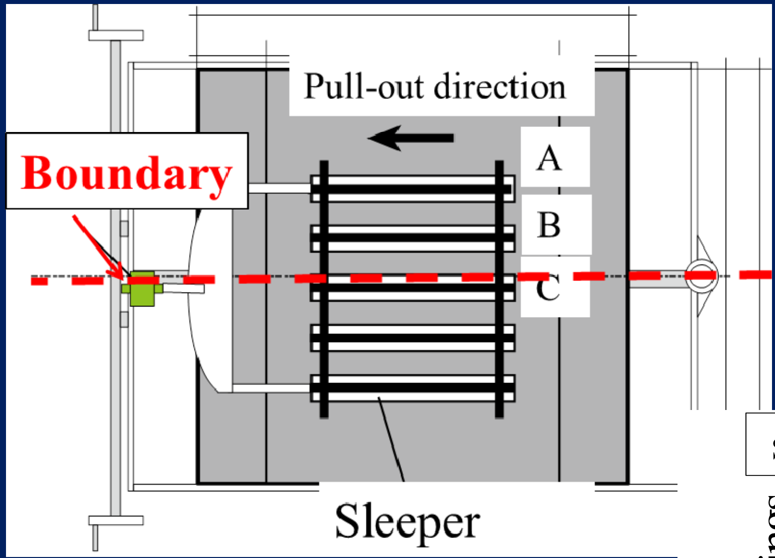


The more away from the structure boundary, reduction of the lateral resistance is less significant.

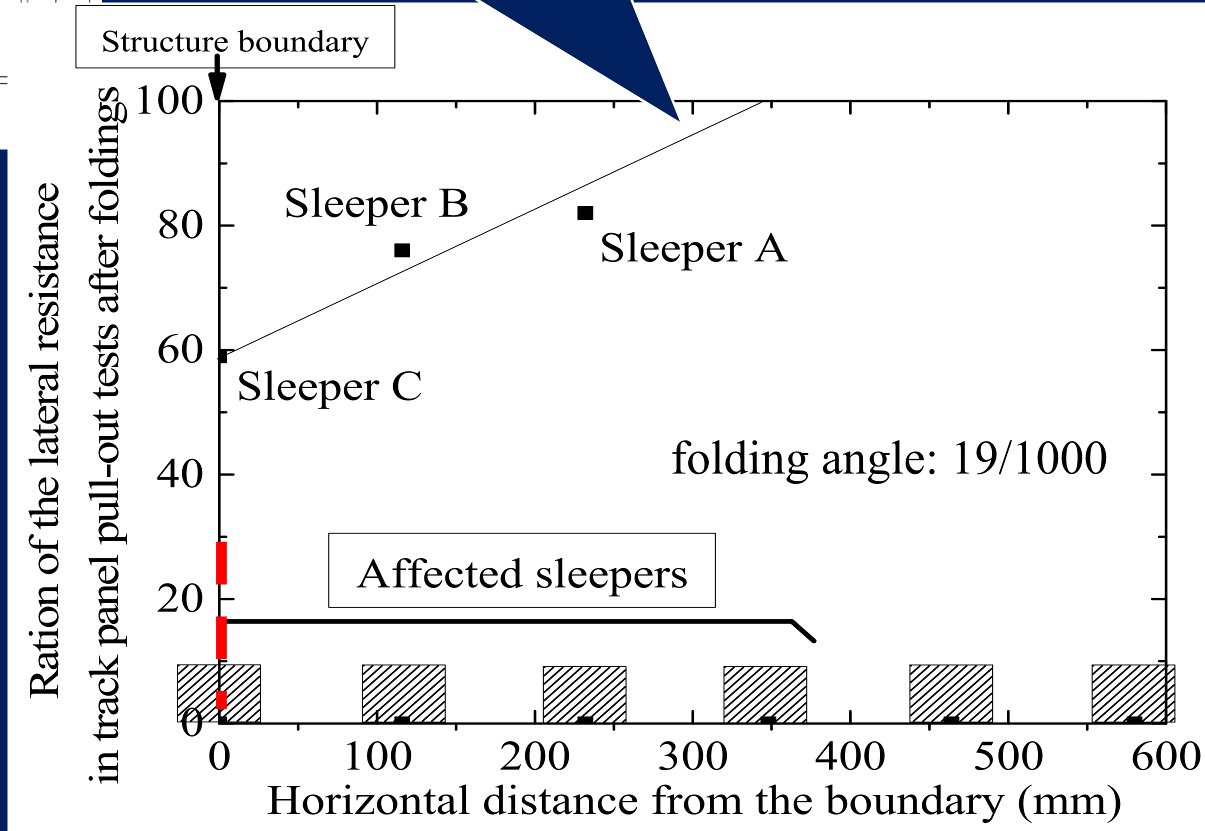


The lateral resistance of sleeper C just above the boundary is similar to that from the single pull-out test after folding.

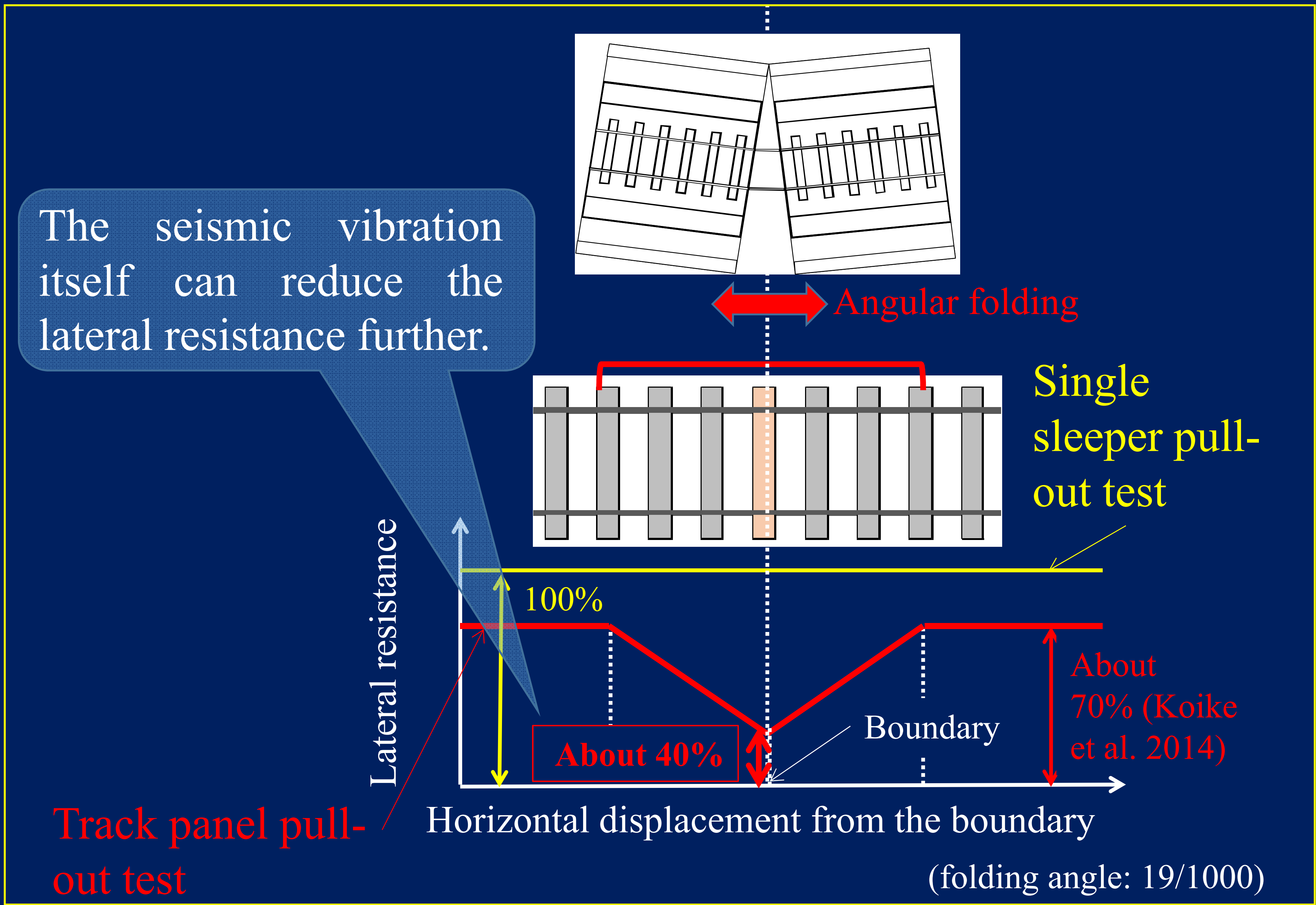
Change of lateral resistance of each sleeper



Assuming the linear relationship, the area affected by the angular folding was estimated.



Ratio of lateral resistance of each sleeper before folding to that after folding



Schematic image of the effect of angular folding on the lateral resistance of railway ballasted track on an elevated bridge

Conclusions

1. Physical modeling methods which simulate angular folding of ballasted tracks at boundaries between structures were attempted.
2. Folding experience reduced the lateral resistance of ballasted tracks. With the increase of folding angle, the lateral resistance reduced.
3. The lateral resistance was sharply decreased by the first folding, but reduced little beyond the first loading when the maximum folding angle remained constant.
4. The more away from the structure boundary, reduction of the lateral resistance became less significant.
5. Based on the experimental results, track area affected by the folding was suggested. Reduction rate of the lateral resistance by the folding was also proposed.

Thank you very much for your kind attention.