Lateral Resistance Characteristics of Ballasted Tracks with Countermeasures against Rail Buckling

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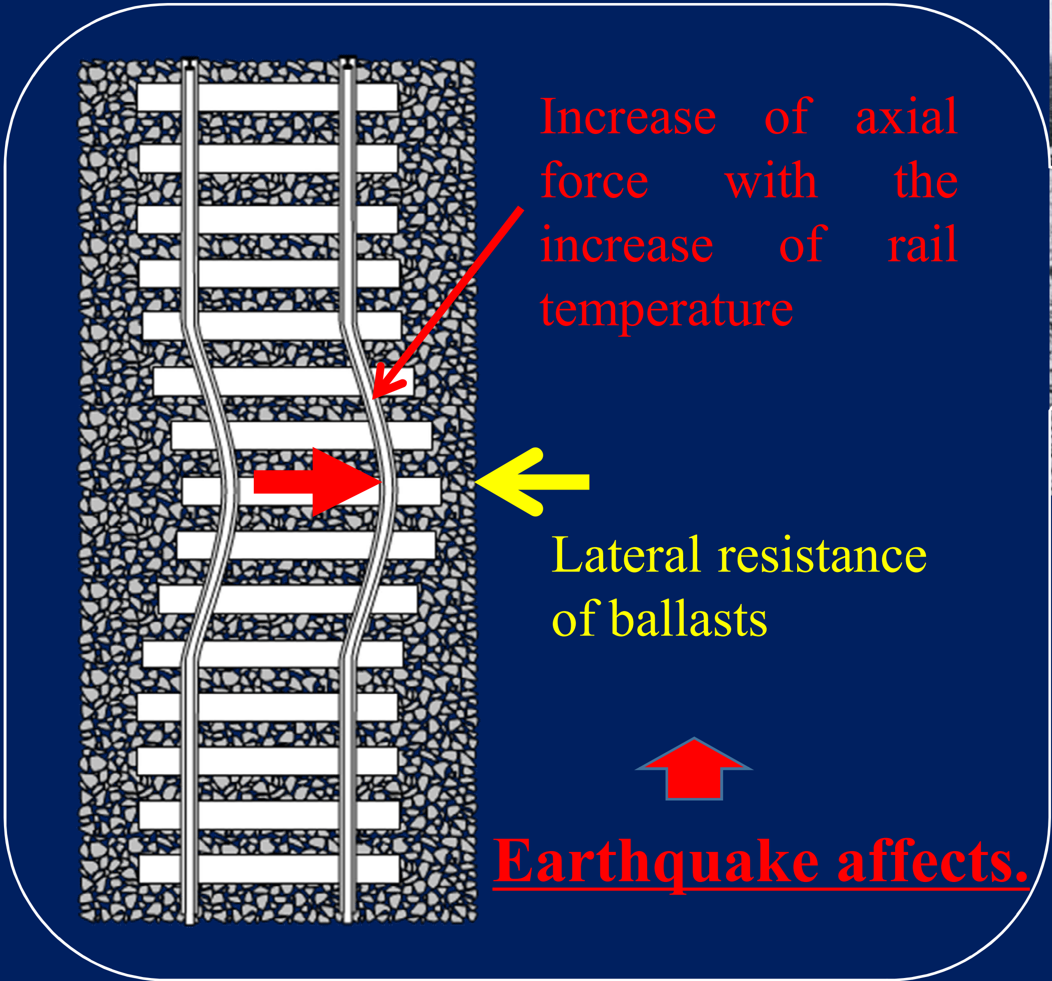
Background

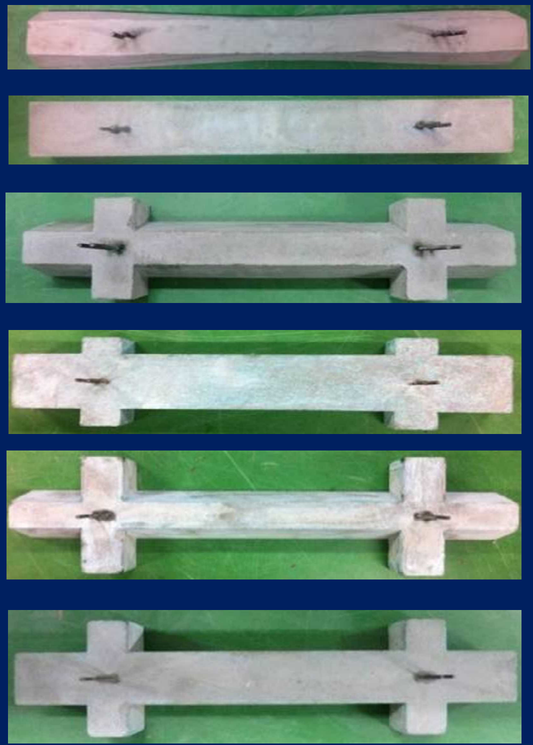


Damage observed after an earthquake (Momoya et al. 2013)

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

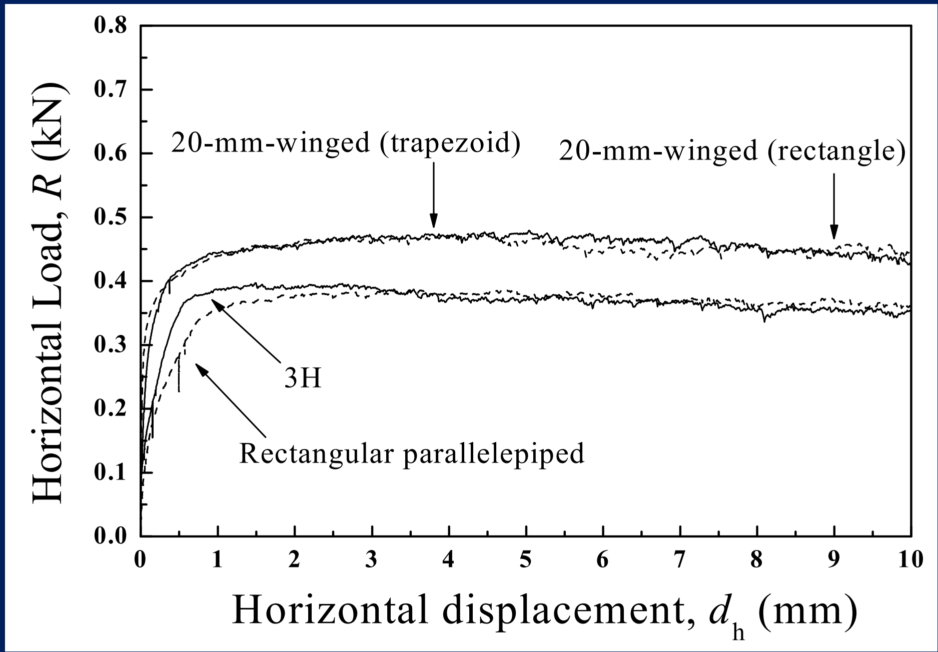
Shaking table tests on a full-scale ballasted track (Nakamura et al. 2014)

Koike et al. (2014) performed single-sleeper pull-out tests and track panel pull-out tests in the laboratory on 1/5-scale models to evaluate the lateral resistance of ballasts with various shapes of concrete sleepers.



Sleepers prepared for model tests (Koike et al. 2014)

Track panel pull-out test on1/5-scale models (Koike et al. 2014)



Horizontal loads and horizontal displacements relationships from track panel pull-out tests (Koike et al. 2014)

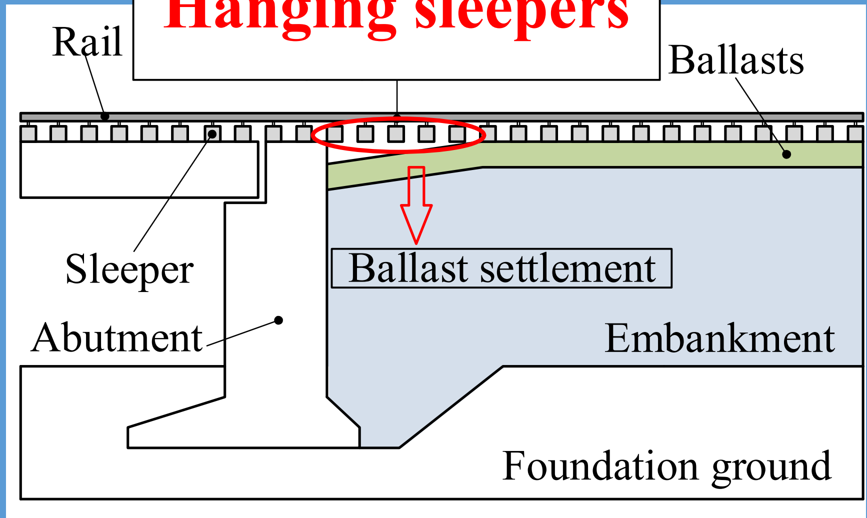
They found the effects of winged sleepers on the lateral resistance of ballasts under various conditions.

Winged sleepers are introduced in one of high-speed railways to increase the lateral resistance of ballasts.

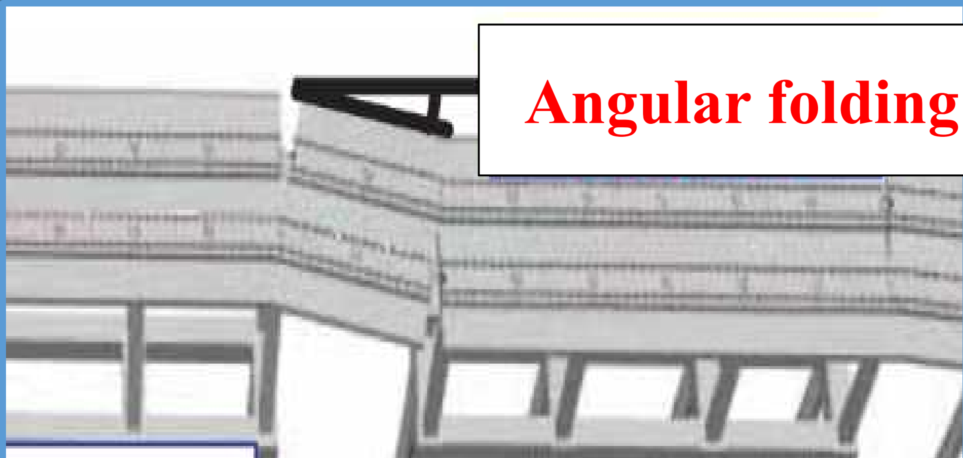
Winged sleepers implemented in a line

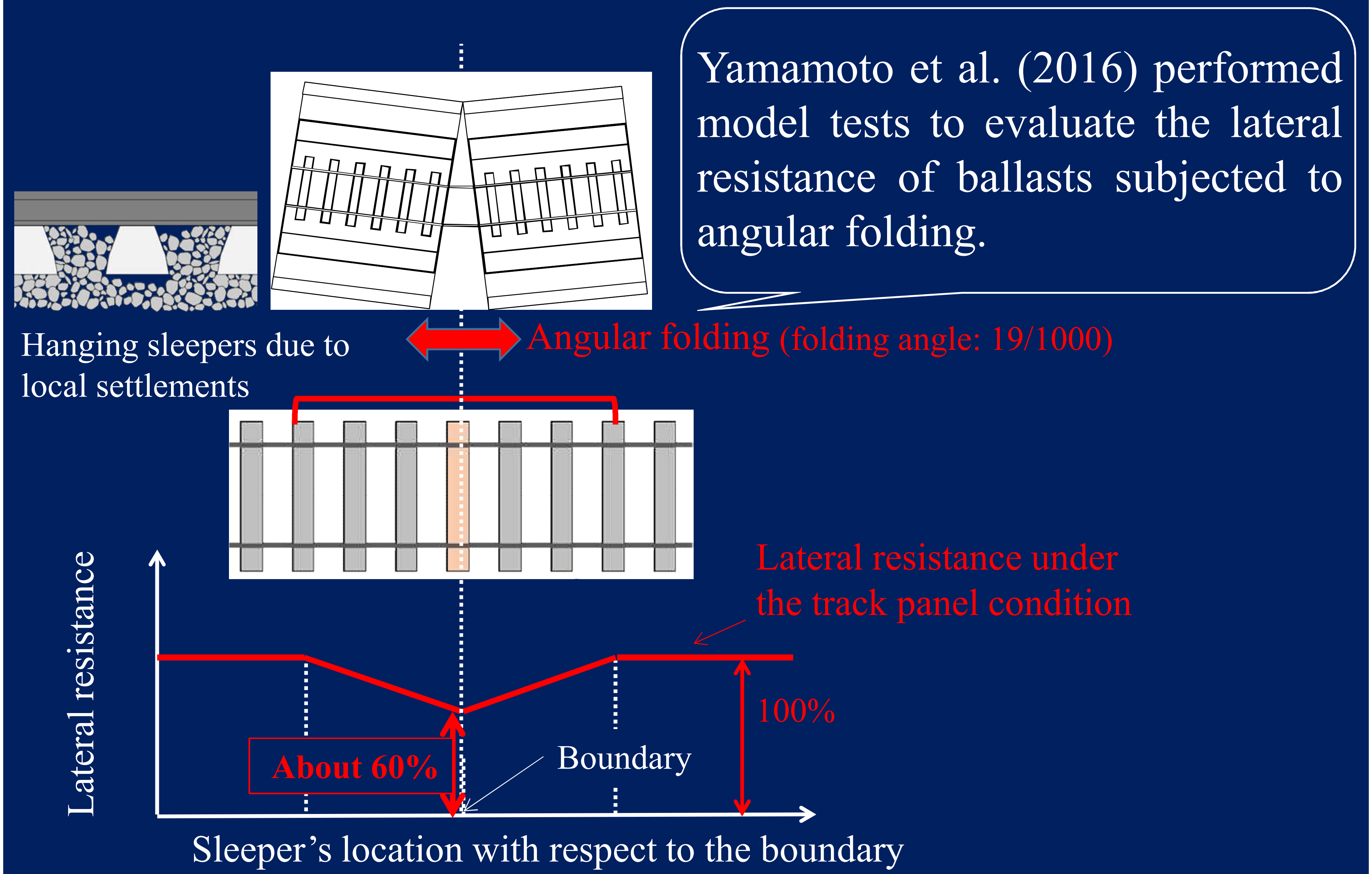
However, the ballasts at transition zones or structure boundaries are affected not only by seismic motions but also local settlements.

Hanging sleepers

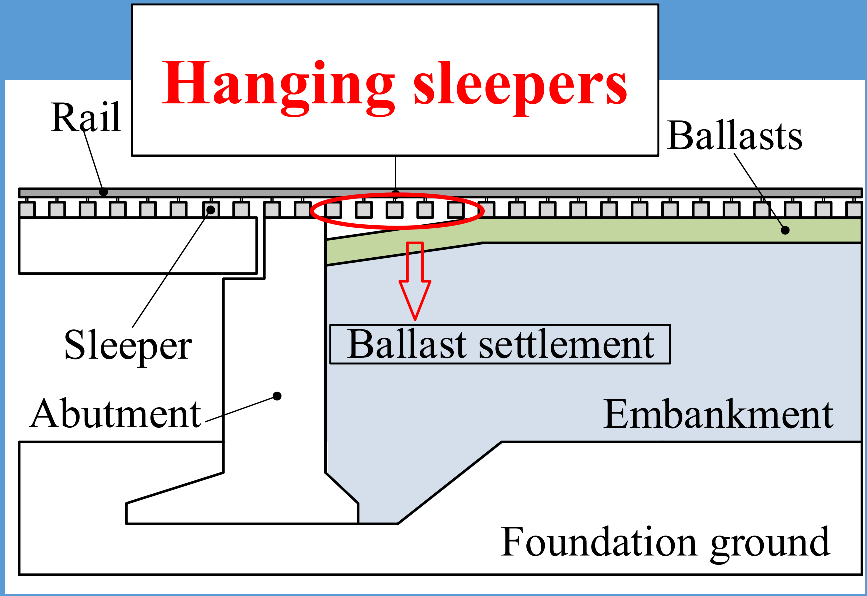


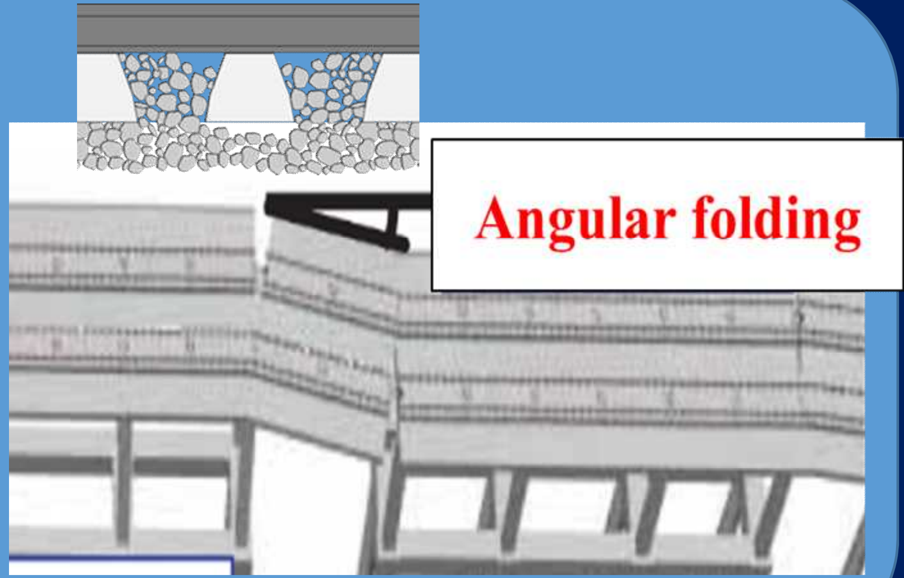
Angular folding





Schematic image of the effect of angular folding on the lateral resistance of railway ballasted track (modified after Yamamoto et al. 2016)





Lateral resistance of ballasts subjected to local settlements at transition zones or structure boundaries should be increased by appropriate countermeasures.

Installation of buckling prevention plates to sleepers are expected instead of winged sleepers, though more time and efforts may be necessary to install them at sites.

Buckling prevention plate

The increase of the lateral resistance of ballasts can be expected by the installation of buckling prevention plates to sleepers. However the lateral resistance can be affected by several factors such as the size and shape of plates, as well as the sleepers' hanging situation. They have not been well investigated so far.

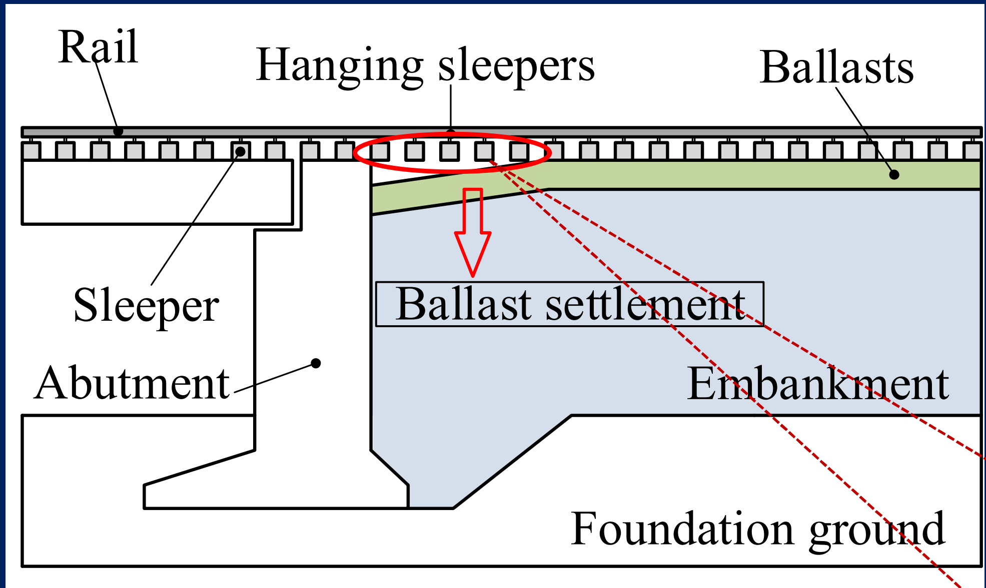
Objectives

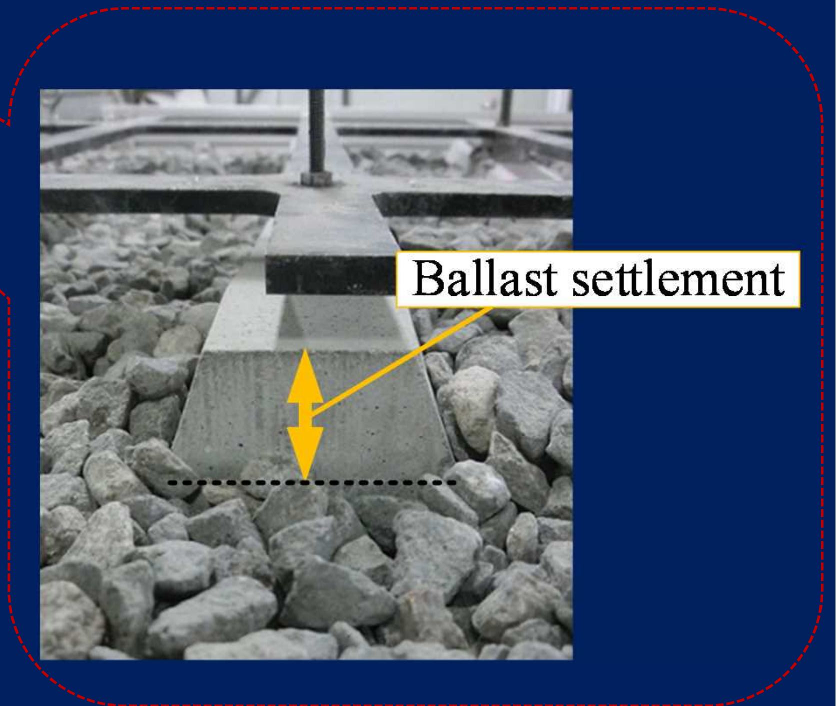
From scaled model tests, lateral resistance characteristics of ballasts in which sleepers are equipped with bucking prevention plates are investigated.

The followings are investigated in detail.

1) Effects of sleepers' hanging situation on the lateral resistance.
2) Effects of size and shape of plates on the lateral resistance.

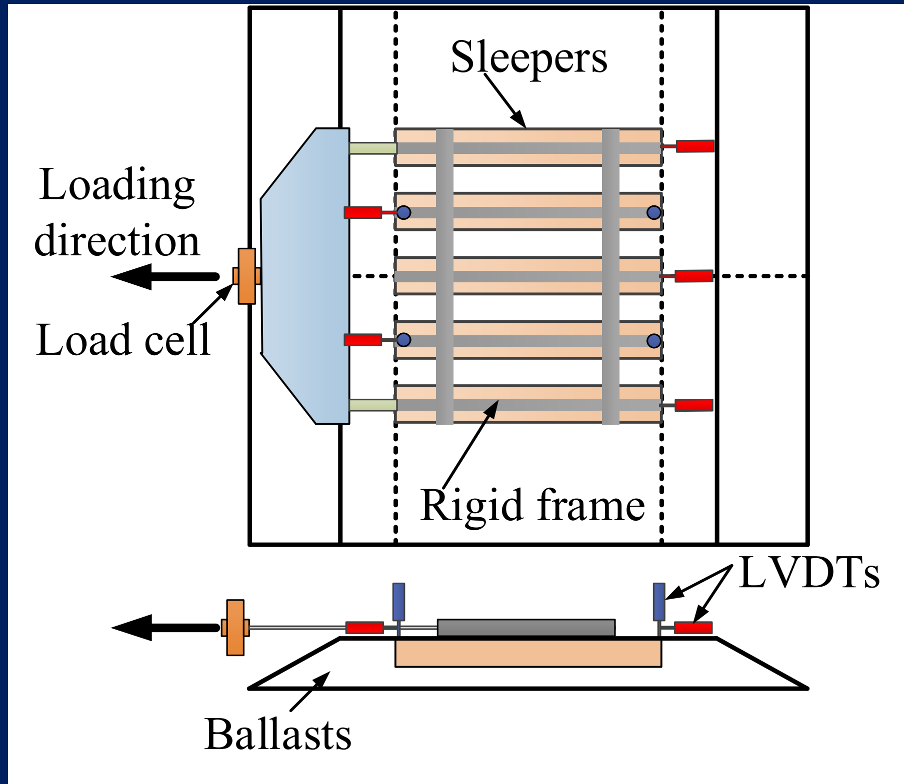
Effects of sleepers' hanging situation on the lateral resistance



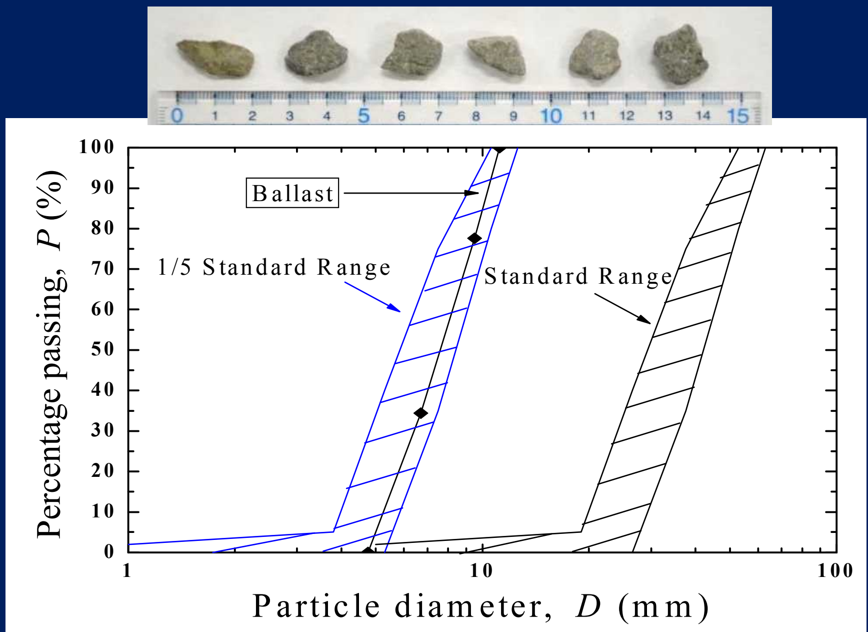


1/5th scale model for track panel pull-out test

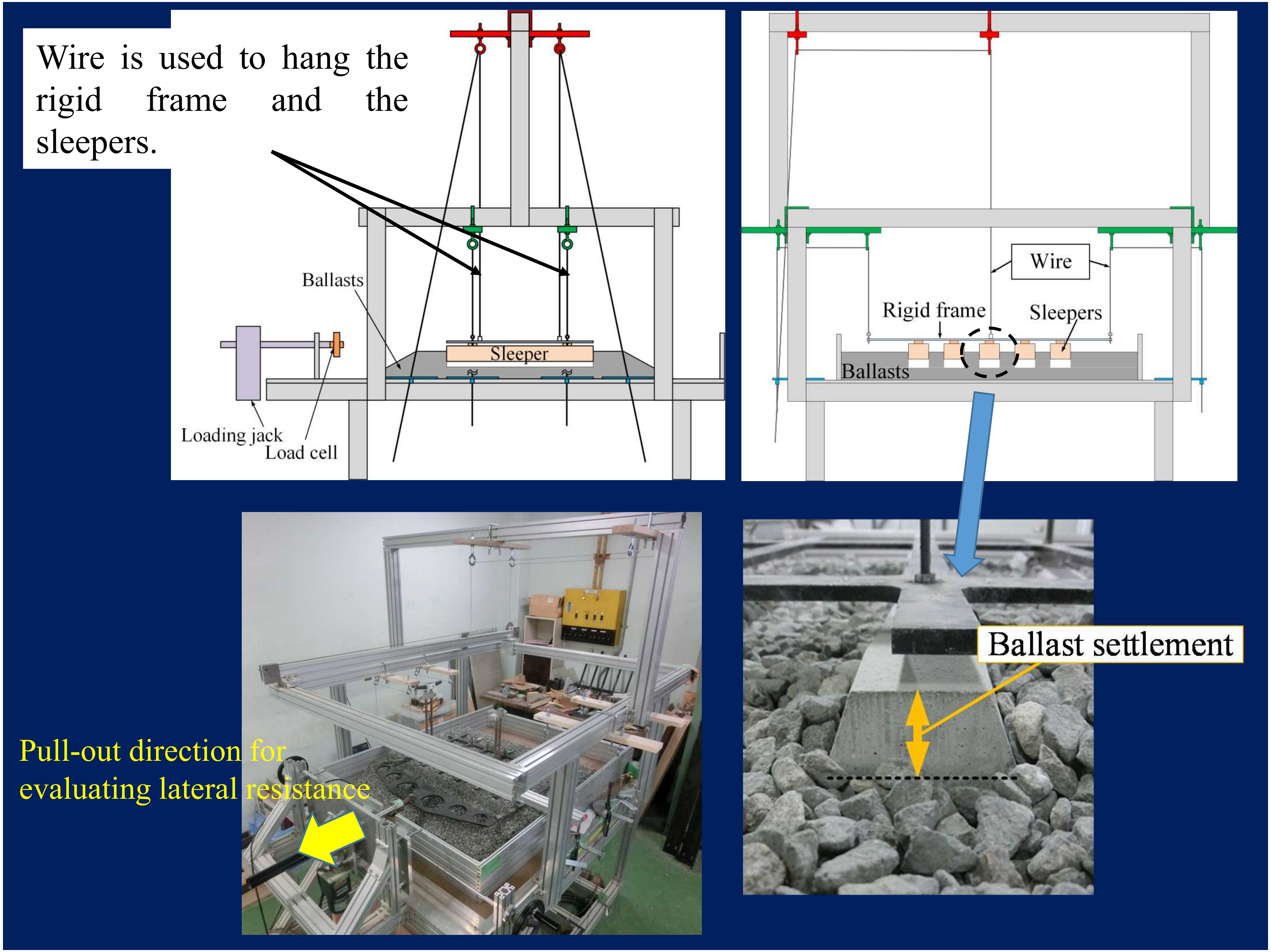
Dry density of 1.60 g/cm^3

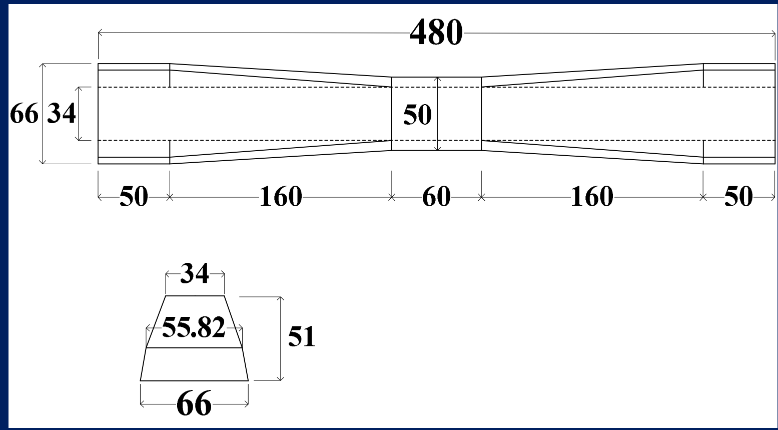


Track panel pull-out test with five sleepers

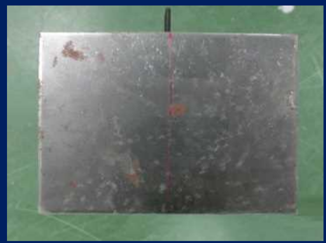


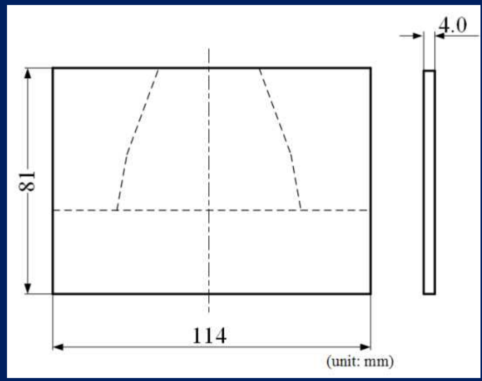
Parallel gradation of PSD


Wire is used to hang the rigid frame and the sleepers.
Ballasts
Sleeper
Loading jack
Load cell
Wire
Rigid frame
Sleepers
Ballasts
Ballast settlement
Pull-out direction for evaluating lateral resistance



3H sleeper (in 1/5th scale)
Ballast settlement *S* =0, 10, 20, 30mm

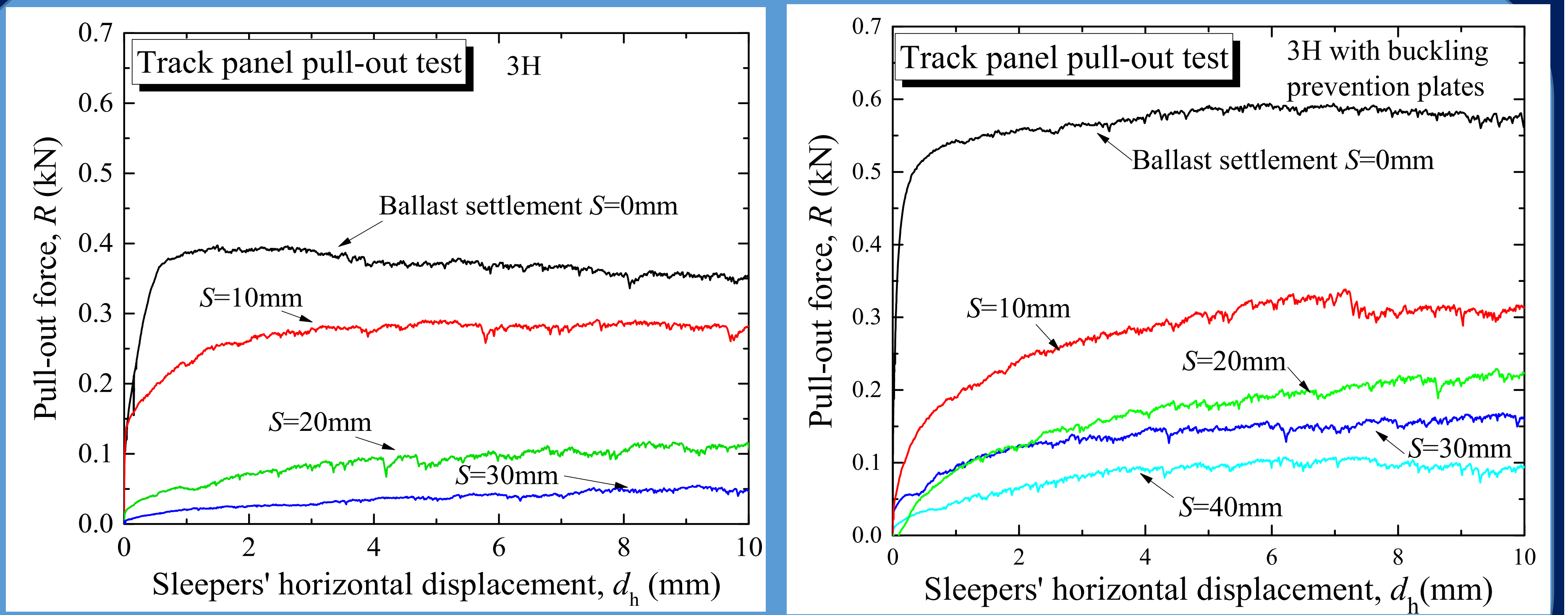




3H sleeper with buckling prevention plates (in 1/5th scale)
Ballast settlement *S* =0, 10, 20, 30, 40mm

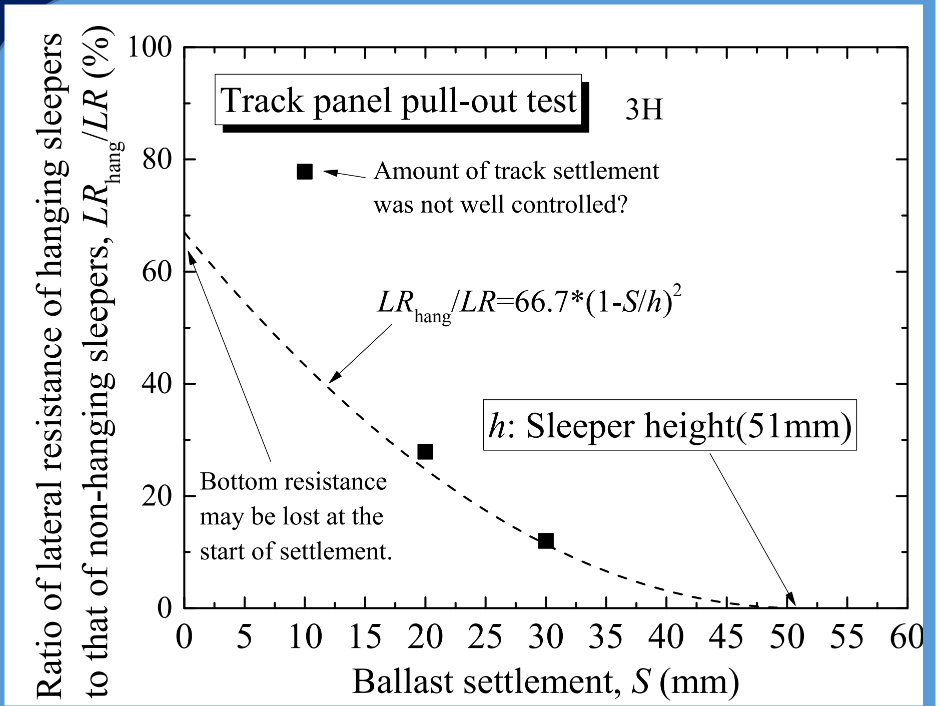
Test cases for pull-out tests

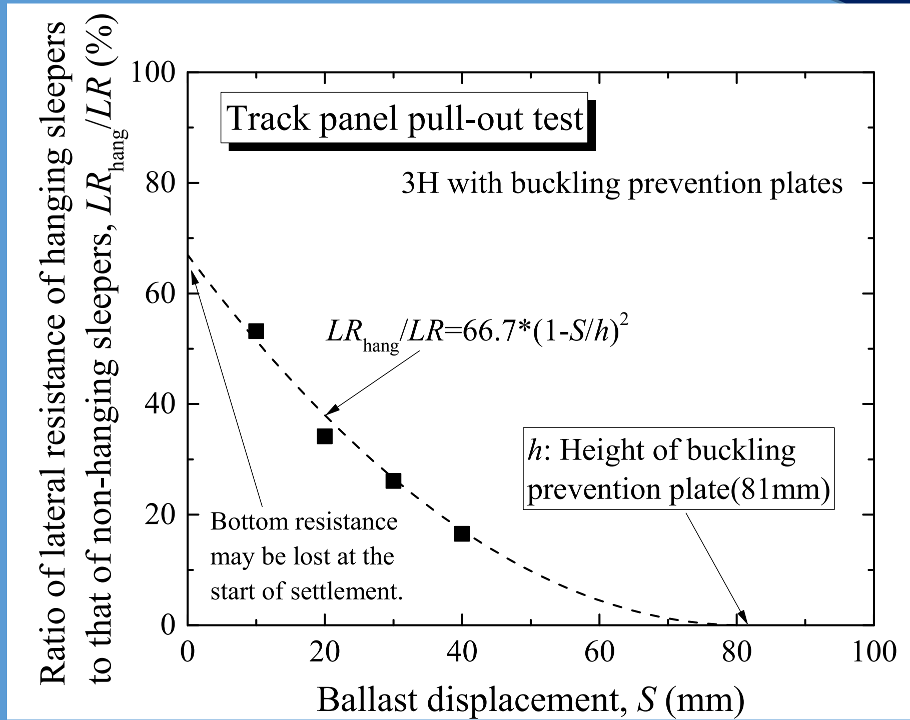

Pull-out direction for
evaluating lateral resistance



Horizontal loads and horizontal displacements relationships from single sleeper pull-out tests

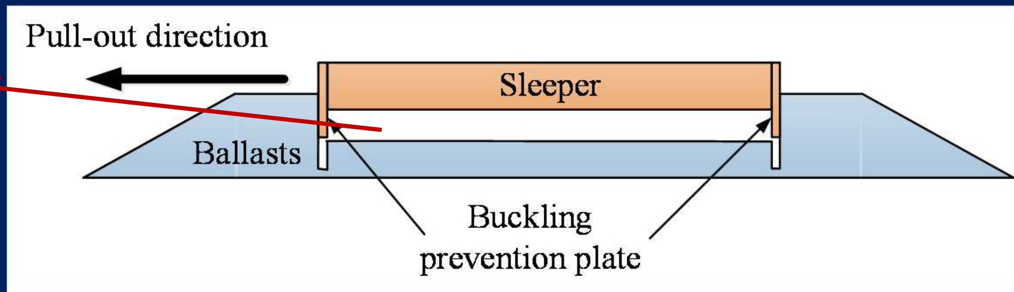
With increase of ballast settlement the lateral resistance of sleepers reduces irrespective of installation of buckling prevention plates. Sleepers with buckling prevention plates show lateral resistance higher than that of sleepers without buckling prevention plates.





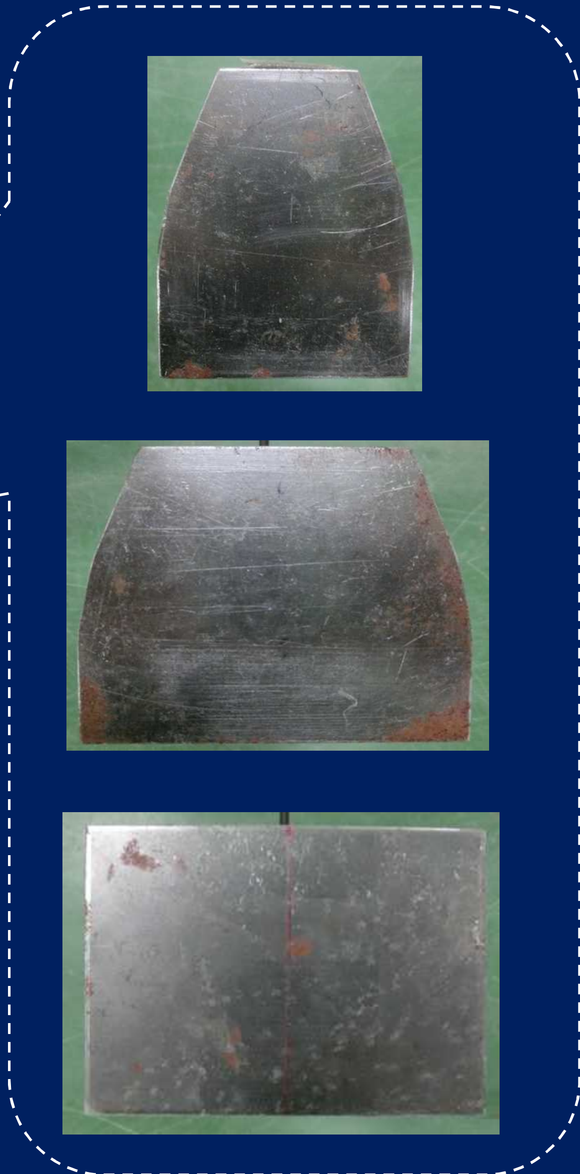
Ratio of lateral resistance of hanging sleepers to that of non-hanging ones plotted against ballast settlements

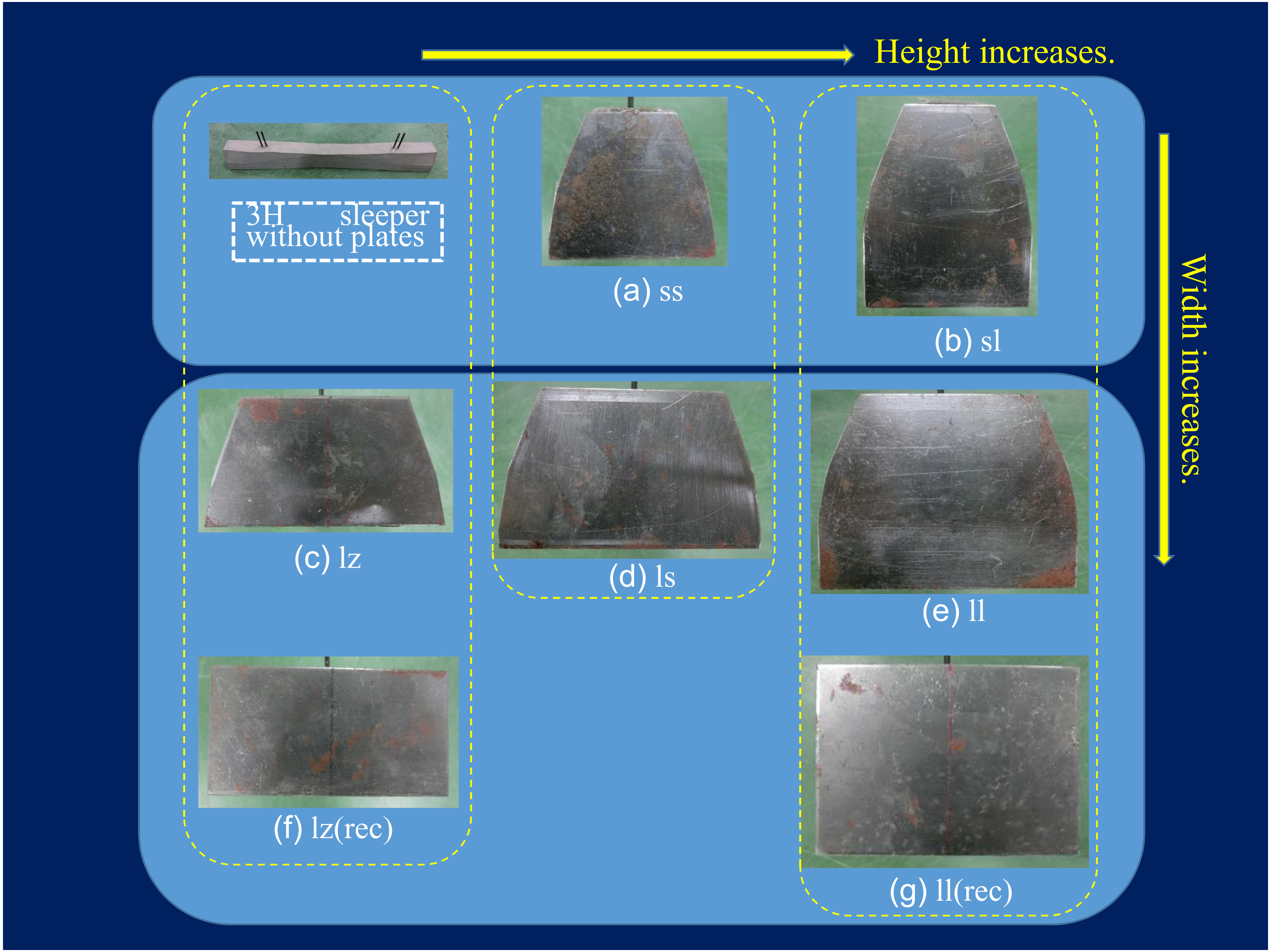
Bottom resistance disappear at the start of settlement.

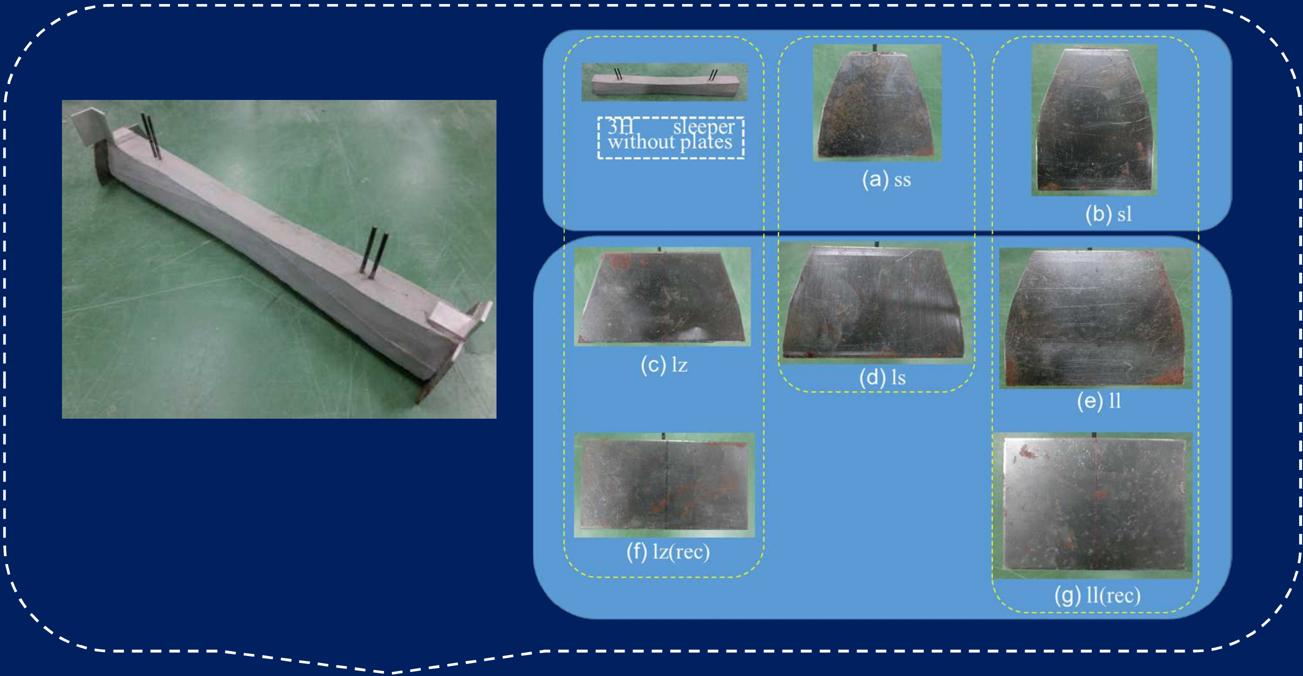


The ratio of lateral resistance of hanging sleepers to that of non-hanging sleepers is reduced with increase of ballast settlement. The ratio can be estimated by the proposed equation.

Effects of size and shape of plates on the lateral resistance

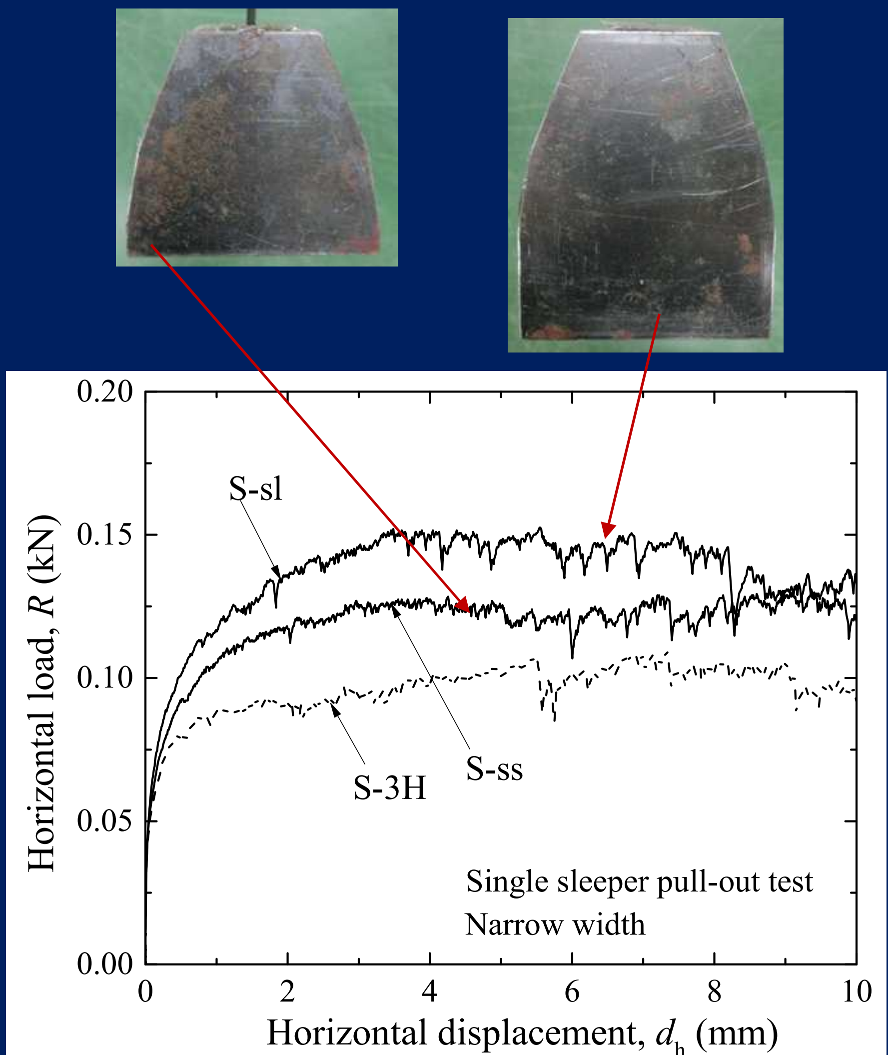



Height increases.
Width increases.
3H sleeper without plates
(a) ss
(b) sl
(c) lz
(d) ls
(e) ll
(f) lz(rec)
(g) ll(rec)

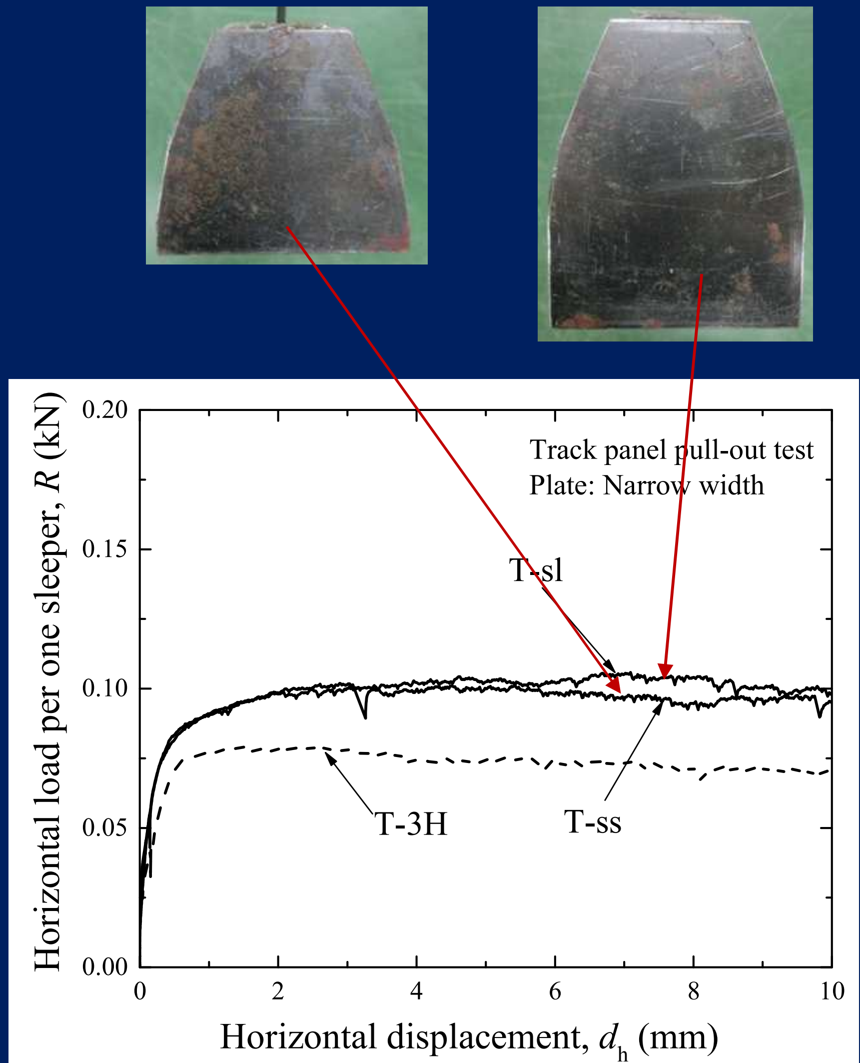


Single-sleeper pullout tests

Track panel pullout tests

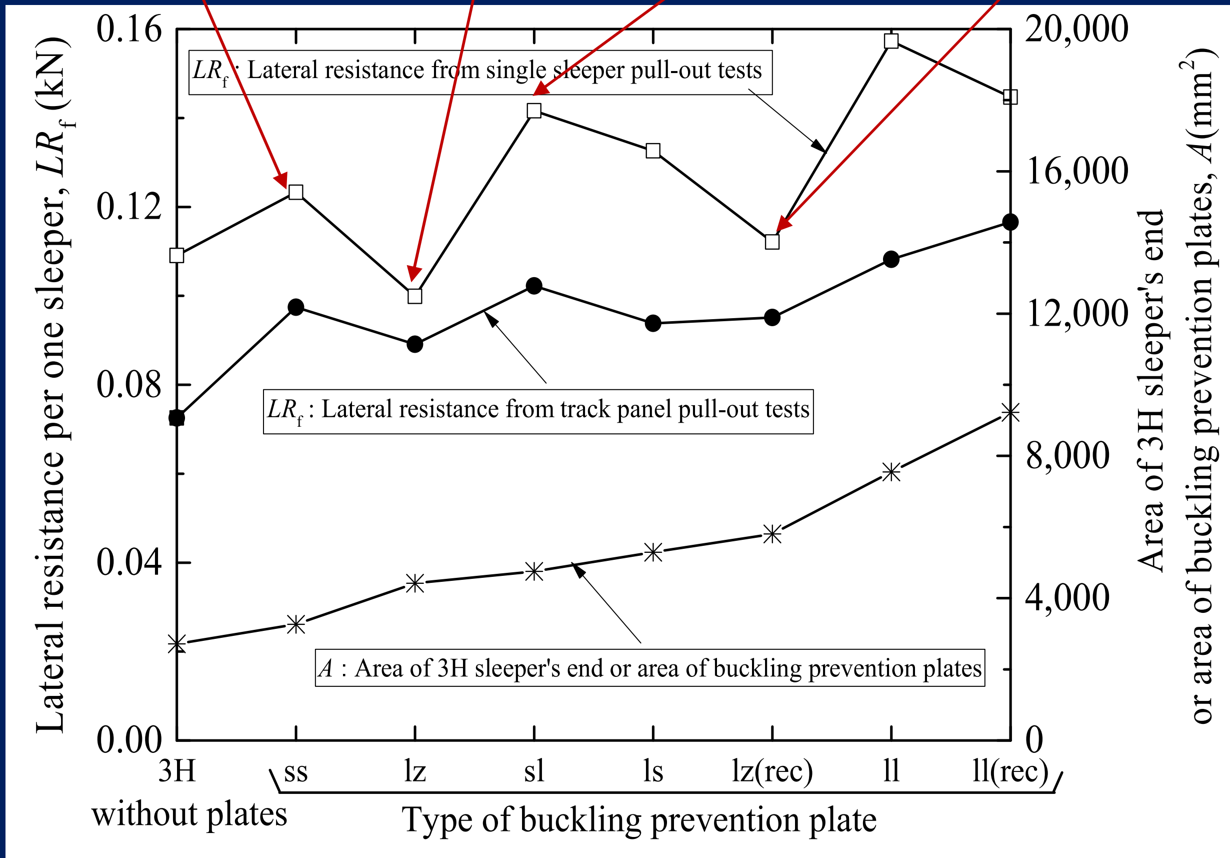


Horizontal loads and horizontal displacements relationships from single sleeper pull-out tests



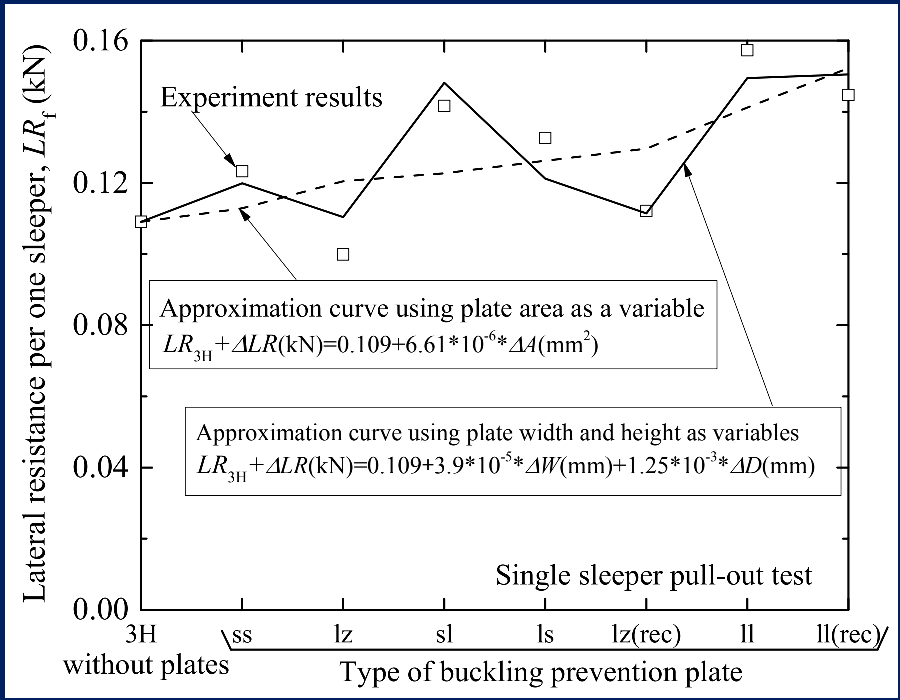
Horizontal loads and horizontal displacements relationships from track panel pull-out tests

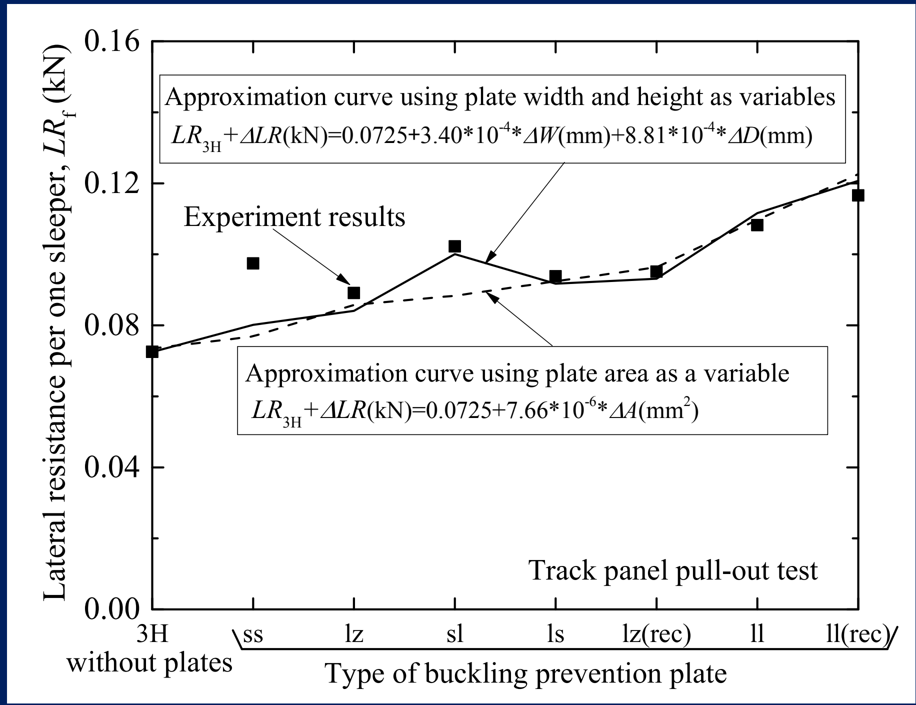
Lateral resistance of ballasts increase with increase of plate height. However the degree of depends on the pull-out test type.



Lateral resistance obtained from different type of buckling prevention plates and the respective plate's area

Lateral resistance of ballasts do not always increase with increase of plate area. This tendency is remarkable in the single sleeper pull-out test compared to the track panel pull-out test.



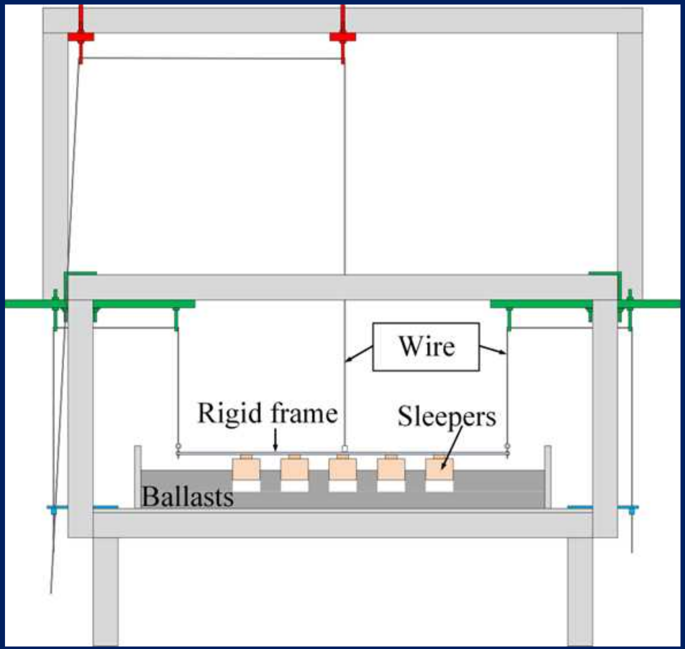


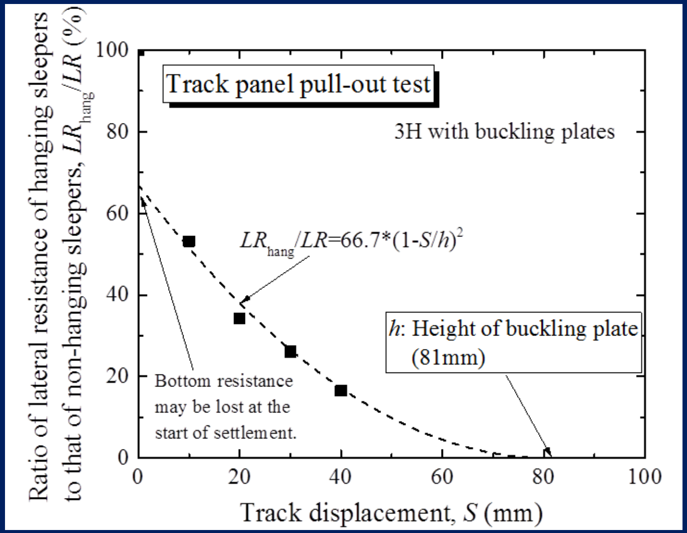
Lateral resistance obtained from different type of buckling prevention plates together with approximation curves

Approximation curve using plate width and height as variables gives better agreement with experimental results rather than that using plate area. The effect of plate height is more significant than that of the plate width.

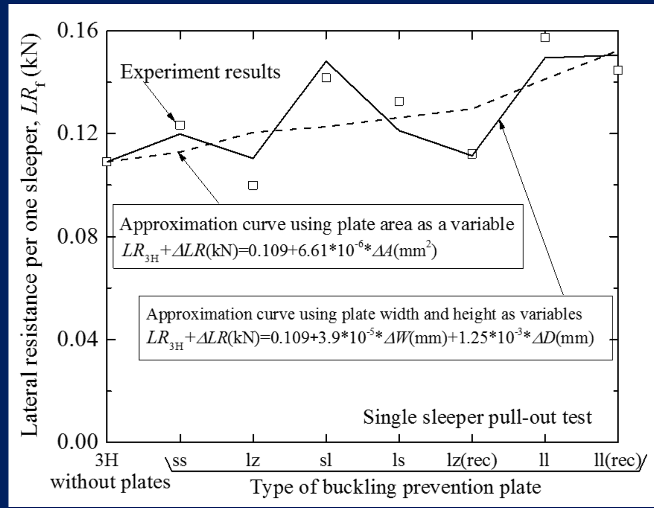
Conclusions

1. A scaled model test method for evaluating lateral resistances of ballasted tracks where hanging sleepers are appeared due to ballast settlement is developed.
2. The test results showed that with increase of ballast settlement the lateral resistance is reduced. Sleepers with buckling prevention plates show lateral resistance higher than that of sleepers without buckling prevention plates.
3. The ratio of lateral resistance of hanging sleepers to that of non-hanging sleepers is estimated by the simple equation which considers the sleeper height or the buckling prevention plate height.





4. Lateral resistance of ballasts increase with increase of plate height. However the degree depends on the pull-out test type.
5. Lateral resistance of ballasts do not always increase with increase of plate area. This tendency is remarkable in the single sleeper pull-out test compared to the track panel pull-out test.
6. Approximation curve using plate width and height as variables gives better agreement with lateral resistance obtained from experiments rather than that using plate area. The effect of plate height is more significant than that of the plate width.



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