BENCHMARK COMPARISON

LY TWINSA vs Z24 SHM Benchmark Comparison

v20260514.13–benchmark

SOTA–LEVEL STATE MATCHING

Z24 is a classic SHM benchmark from a controlled damage test before demolition in Switzerland. LY is an in–service TWINSA case for matching support–reaction constraint states. This page does not make a generic algorithm claim; it compares state–identification resolution in engineering units.

The published Z24 benchmark shows that 20 mm pier settlement can be detected and localized by vibration–based SHM, and 15%~38% stiffness changes can be recovered through FEMU. The LY case further reports three verifiable state quantities: 0.67 mm pier–equivalent elevation, span–scaled girder stiffness resolution, and closure between measured and predicted support–reaction load distribution.

77×

20 mm / 0.26 mm

Same–scale elevation resolution

Z24: 20 mm pier settlement can be detected and localized. LY: 2.00 mm single–bearing lift gives a 0.67 mm pier–equivalent state; scaled to the 58 m Z24 length, this is about 0.26 mm.

47~119×

span–scaled

includes L^3 span lever

Girder stiffness resolution · span–scaled

Using the L^3 lever of girder bending response: $[(15\sim38) / 5] \times (75 / 30)^3 \approx 47\sim119$. The value is an equivalent comparison at response scale.

0→1

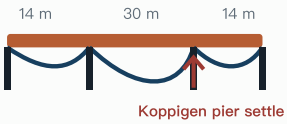
load distribution

SOTA–level

Reference–state identification · SOTA–level

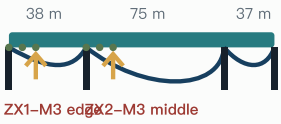
Traditional Z24–type SHM mainly identifies damage, stiffness, or resistance states, and usually does not close support–reaction distribution. LY TWINSA includes the 12–bearing load distribution in state matching; after the event update, RMSE improves from 197 to 32 kN.

BACKGROUND Bridge and test context



Z24 Bridge · Swiss benchmark

A three–span prestressed concrete box–girder bridge, 14 + 30 + 14 m, with a total length of 58 m. Before demolition in 1998, it underwent one year of monitoring and progressive damage testing. The Koppigen pier was lowered by 20 / 40 / 80 / 95 mm, making the bridge a standard dataset for vibration–based SHM and FEMU.



LY Bridge · in–service case

A three–span continuous steel box–girder bridge with variable depth and width, 38 + 75 + 37 m, about 150 m total length, and 12 spherical steel bearings. From 2024–12–25 to 2024–12–30, the field adjustment lifted ZX1–M3 and ZX2–M3 by +2.00 mm each: one in an edge support group and one in a middle support group.

SETTLEMENT BENCHMARK Same–scale comparison of settlement and equivalent elevation

20 mm and 0.67 mm are not directly comparable; first scale them to the same bridge length

77×

state resolution

The Z24 value of 20 mm is a pier–settlement detection level on a 58 m bridge. The LY value of 0.67 mm is a pier–uniform elevation component on a 150 m bridge. After total–length scaling, LY corresponds to about 0.26 mm on the Z24 scale.

Object	Ratio to Z24 20 mm	Value	Basis
Z24 pier settlement		20 mm	Detection / localization
LY pier–equivalent		0.67 mm	State quantification
LY scaled to Z24		0.26 mm	Same–scale quantification

Conversion: A 2.00 mm single–bearing event gives a three–bearing pier–uniform component of 2.00 / 3 ≈ 0.67 mm. The Z24 / LY total–span ratio is 58 / 150, so 0.67 × 58 / 150 ≈ 0.26 mm. Then 20 / 0.26 ≈ 77.

STIFFNESS BENCHMARK Stiffness resolution: span–scaled comparison

Use the L^3 lever to scale stiffness resolution to response scale

47~119×

span–scaled

Teughels & De Roeck, JSV 2004 reports Z24 stiffness-parameter updates of 180 → 157 and 200 → 145, corresponding to about 1.15× to 1.38×. LY girder stiffness resolution is taken as 5%. The LY main span is 75 m versus 30 m for Z24, so bending response is amplified at the L^3 scale.

Scaling item	Ratio to 119×	Value	Basis
Stiffness difference		(15~38) / 5	Z24 / LY
Span response		15.6×	L^3 lever
Scaled comparison		47~119×	Response scale

Scaling:[(15 to 38) / 5] × (75 / 30)^3 ≈ 47 to 119. This is not a simple parameter-percentage comparison; it also includes the bending-response amplification caused by the longer LY main span.

INTERPRETATION Difference between detection output and quantified state output

Item	Z24 vibration-based benchmark	LY TWINSA state matching
Event type	Controlled damage test on a retired bridge. The Koppigen pier was lowered by 20 / 40 / 80 / 95 mm; known events were used to verify SHM algorithms.	Field bearing lift on an in-service bridge. ZX1-M3 and ZX2-M3 were each lifted by +2.00 mm, and the measured reaction response was used to validate model updating.
Elevation change	The 20 mm stage can be detected and localized; typical outputs are damage index, anomaly class, or damaged-pier location.	The output can be traced back to bearing elevation: 2.00 mm single-bearing event → 0.67 mm pier-equivalent → 0.26 mm on the Z24 scale.
Stiffness change	In reference-state FEMU, stiffness parameters are updated by 1.15× to 1.38×, equivalent to 15% to 38% change.	Girder stiffness is counted at 5% resolution and scaled by the L^3 response lever from the 75 m LY main span versus the 30 m Z24 main span, giving an equivalent comparison of about 47~119×.
Span effect	Z24 has a 30 m main span and a total length of 58 m; stiffness changes are mainly identified through modal FEMU.	LY has a 75 m main span and a total length of about 150 m. At the L^3 scale, the longer span gives about a 15.6× response lever for girder-stiffness changes; this has been included in the front-page 47~119× value.
Load distribution	Traditional SHM often stops at damage index, stiffness update, or resistance-state identification, and usually does not directly close simultaneous support-reaction distribution.	LY TWINSA puts load distribution, temperature, and bearing-elevation events into the same state-matching problem. After the event update, measured and predicted reactions re-close, with mean RMSE improving from 197 to 32 kN.

EVIDENCE Evidence from literature

Source	Conclusion used here	Used for
KU Leuven Z24 benchmark	Z24 geometry and SIMCES background: three spans of 14 + 30 + 14 m, total length about 58 m.	Source for Z24 bridge type and scale.
Maeck, Peeters, De Roeck, 2001	Lists the 20 / 40 / 80 / 95 mm pier-settlement sequence; 20 mm is a controlled damage level usable for detection and localization.	Settlement-event sequence and the 20 mm benchmark.
Teughels & De Roeck, JSV 2004	Identified stiffness parameters in reference-state updating: 180 → 157 and 200 → 145, corresponding to about 1.15× to 1.38×, or a 15% to 38% change level.	Source for the stiffness benchmark and 47~119× scaling.
Sony, Sadhu, 2022	Recent work reuses Z24 20 / 40 / 95 mm pier-settlement cases; at the 20 mm stage, damage index can distinguish the damaged pier.	Benchmark for 20 mm detection / localization.
Nguyen-Tran et al., 2023; Abdrabo, 2024	Recent studies continue to use Z24 as a benchmark for classification, anomaly detection, and online identification; outputs are mostly scenario classes or anomaly decisions.	Shows that recent Z24 outputs remain closer to detection / classification than field state-quantity inversion.

LY stiffness comparison uses 5% girder-stiffness resolution and scales it by the main-span L^3 response lever. Bearing-stiffness autoregression is not used in this benchmark. Load distribution means re-closing the measured and model-predicted reactions of the 12 bearings under the same state variables.

LY data basis: bridge spans 38 + 75 + 37 m. From 2024-12-25 to 2024-12-30, the field bearing-lift event was +2.00 mm at both ZX1-M3 and ZX2-M3. Event-fit improvement comes from `/Users/darcyy/antigravity/xuyunnew/web/twinsa/77d_update_event_corrected_reg.json` 。

v20260514.17-print

LY Road Viaduct BSS-PINN Structural State Inversion and Condition Assessment

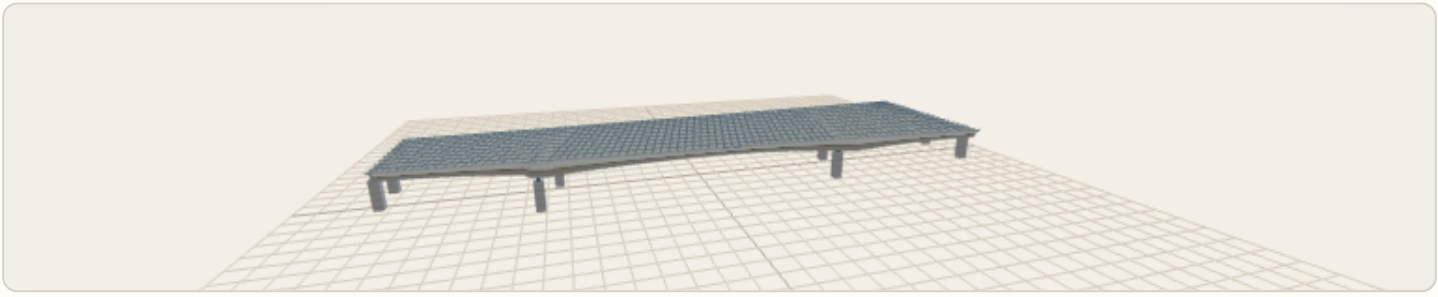
01 · Structure and Measurement

STRUCTURE AND MEASUREMENT

Bridge Layout, Bearing Instrumentation and Measured Reactions

STRUCTURE CONTEXT

3D Model of a Three-Span Continuous Variable-Depth and Variable-Width Steel Box Girder · 38 + 75 + 37 m · 12 Spherical Steel Bearings

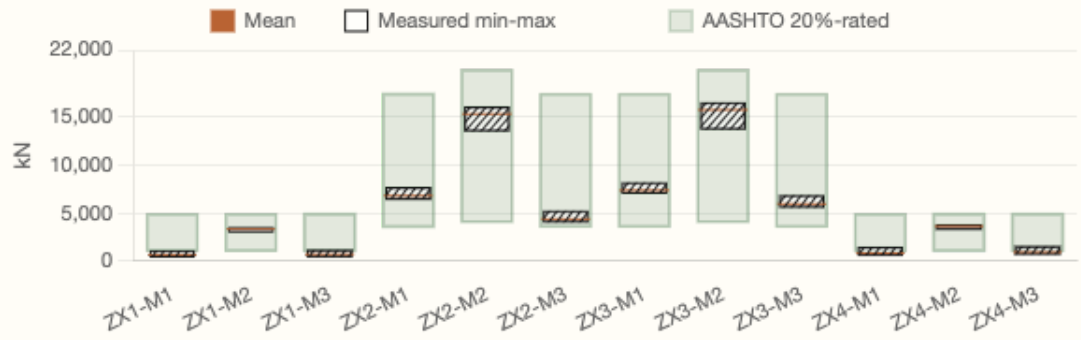


Variable-depth steel box girder Bearing measurement point Mean reaction bar

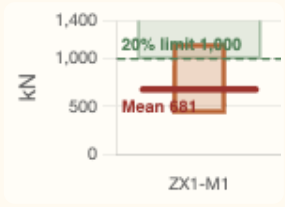
MEASURED FORCE

Measured Envelope of 12 Bearings · Range / Mean / Rated

Each column: measured min-to-max envelope (hatched band) | AASHTO 20% to rated range (green band)



ZX1-M1 detail view low-reaction detail



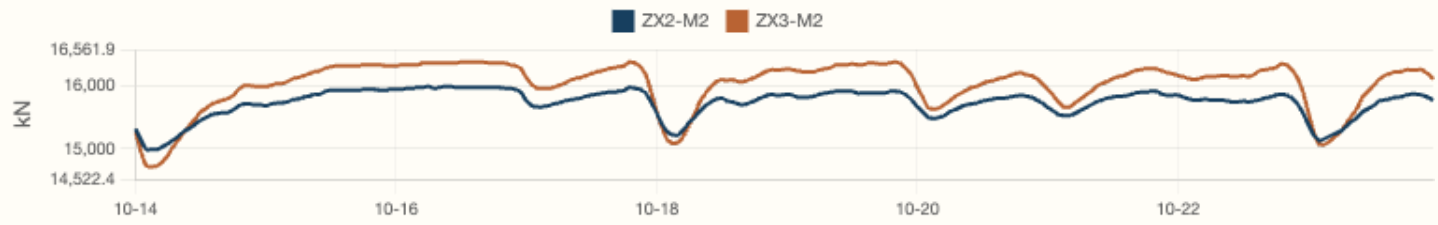
Mean 681 kN; 319 kN below the AASHTO 20% limit.

TIME SERIES

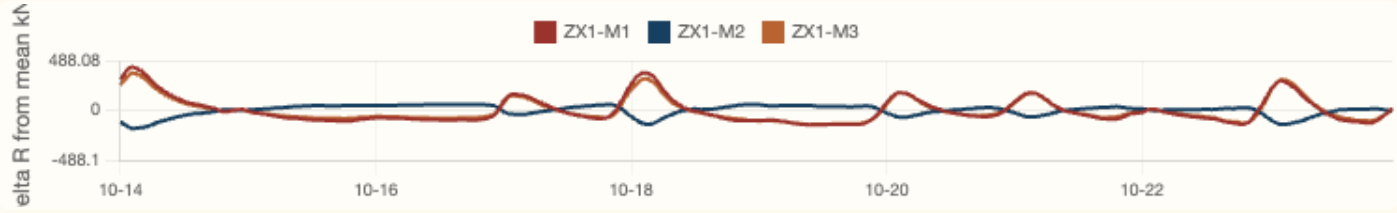
2024-10-14 12:00 → 2024-10-24 11:00 · 240 h · ZX2-M2 / ZX3-M2

12-Bearing Reaction Time History · Range Selectable

The print view uses a fixed local window: the upper chart shows only ZX2-M2 and ZX3-M2 measured reactions, and the lower chart shows the relative rise and fall of the three ZX1 bearings.



ZX1 support bearing line · M1 / M2 / M3 relative change from mean



Model Update Results · Initial Relative Elevation + Structural Parameter Correction

Mean NSE

96.3%

Time-history fit quality; closer to 100% means closer to measured reactions.

Bearing	initial relative elevation
ZX1-M1	−1.89 mm
ZX1-M2	+4.22 mm
ZX1-M3	−2.40 mm
ZX2-M1	−1.64 mm
ZX2-M2	+2.87 mm
ZX2-M3	−1.45 mm
ZX3-M1	−3.24 mm
ZX3-M2	+7.72 mm
ZX3-M3	−3.50 mm
ZX4-M1	−3.53 mm
ZX4-M2	+6.21 mm
ZX4-M3	−3.37 mm

Bearing location

ZX1-M1

initial relative elevation -1.89 mm

parameter location / type	original value	corrected result	factor adjustment
side-span 1 main-gir...	18.17M kN·m²	14.28M kN·m²	−21.5%
main-span main-gird...	31.04M kN·m²	38.72M kN·m²	+24.7%
side-span 2 main-gir...	24.30M kN·m²	20.13M kN·m²	−17.2%
ZX1 piercap-beam EI...	29.03M kN·m²	26.41M kN·m²	−9.0%
ZX2 piercap-beam EI...	186.02M kN·m²	221.70M kN·m²	+19.2%
ZX3 piercap-beam EI...	186.02M kN·m²	182.26M kN·m²	−2.0%
ZX4 piercap-beam EI...	29.03M kN·m²	33.66M kN·m²	+16.0%
12 bearing springs K...	11,250 kN/mm	11,195 kN/mm	−0.5%
self-weight + pavem... load	65,868 kN	67,418 kN	+2.4%

parameter location

side-span 1 main-girder EIY

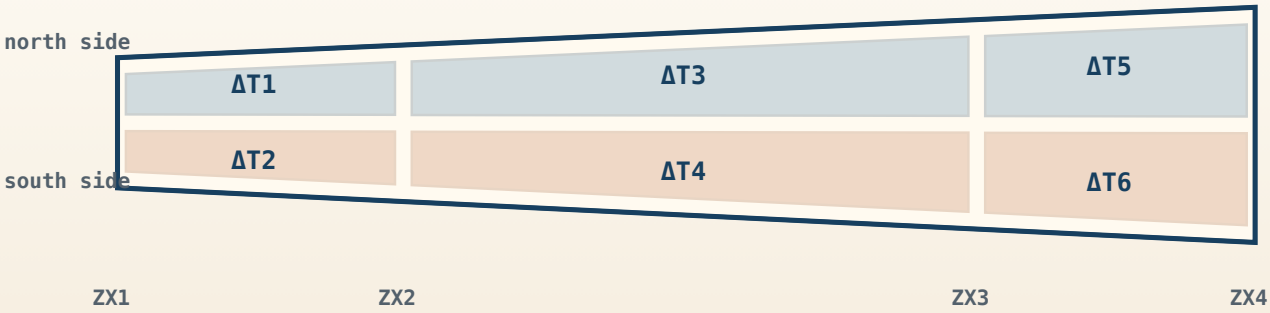
correction factor -21.5% · side span 1main-girder EIY

6 TEMP GRADIENTS

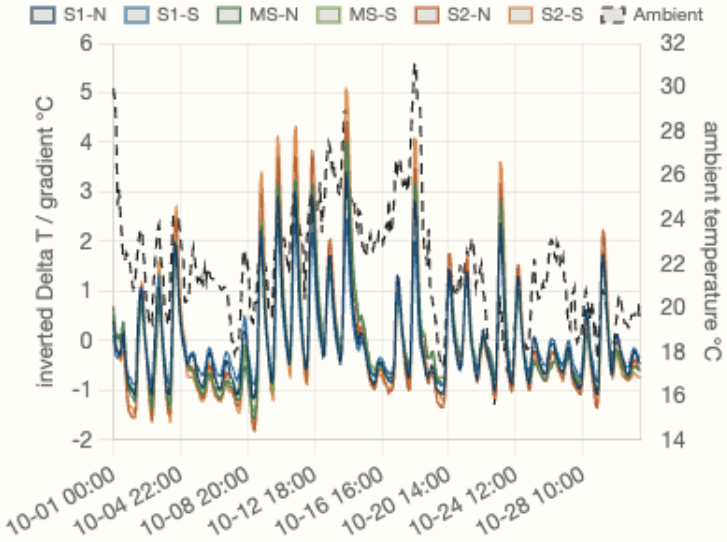
Six inverted temperature modes · time history

Locations of the six temperature-gradient modes

One bridge plan view with north and south zones shown separately.



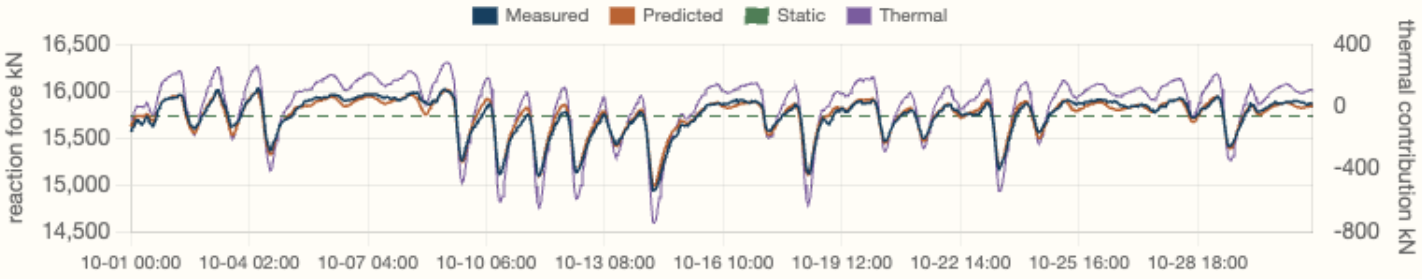
Delta T1/2 correspond to side span 1, Delta T3/4 to the main span, and Delta T5/6 to side span 2; the upper row is north and the lower row is south.



MEASURED VS PREDICTED

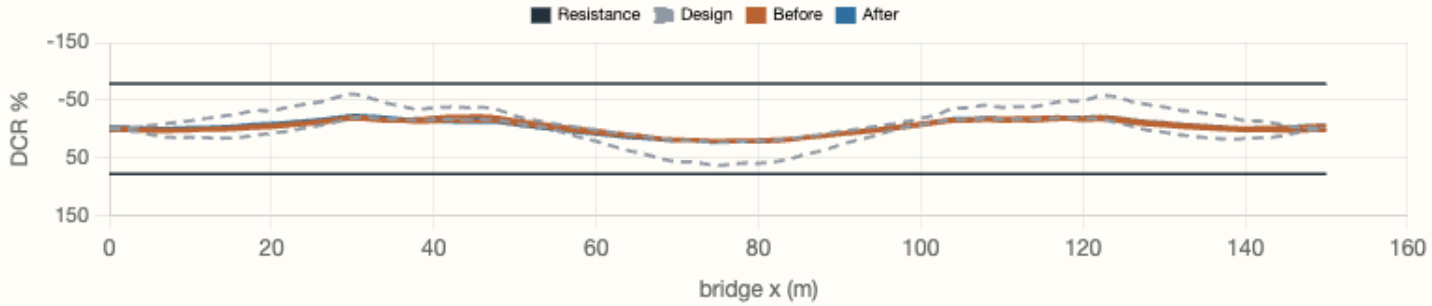
Measured reaction time history vs temperature-gradient-driven prediction

Channel ZX2-M2



LONGITUDINAL GIRDER

Longitudinal main-girder flexural DCR / LRFR comparison



Measured section DCR max
29.6%
full section Sigma My / Sigma M_cap · x=76.0m · LRFR 3.37

AASHTO design section DCR max
80.6%
full section Sigma My / Sigma M_cap · x=76.0m · LRFR 1.24

Measured strip DCR max
63.9%
local strength · x=114.0m · y=20.2m · eid 770

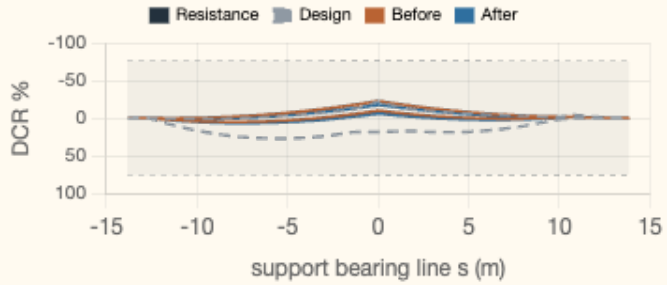
AASHTO design strip DCR max
145.1%
local strength · x=124.0m · y=20.6m · eid 775

Transverse simplified-model DCR max
52.3%
ZX4 · s=0.0m · measured envelope controls

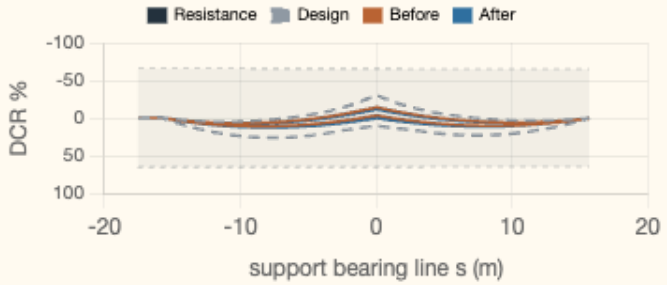
TRANSVERSE SIMPLIFIED MODEL

Transverse simplified model: flexural DCR curves of four bearing lines

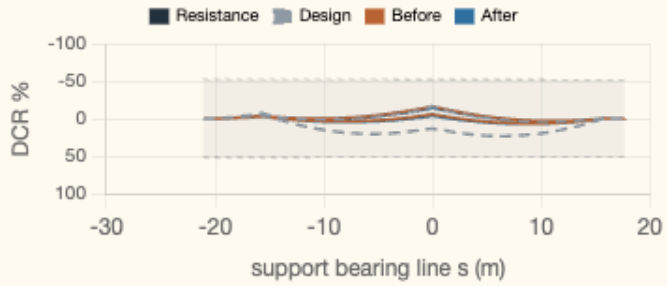
ZX1 s=-13.9–13.9m · measured |M| 10,485 · design |M| 12,487 kN·m · local My ratio ×3.20



ZX2 s=-17.5–15.7m · measured |M| 28,452 · design |M| 58,719 kN·m · local My ratio ×1.31



ZX3 s=-21.1–17.7m · measured |M| 41,555 · design |M| 57,506 kN·m · local My ratio ×1.94



ZX4 s=-21.7–20.5m · measured |M| 17,853 · design |M| 10,293 kN·m · local My ratio ×2.89

ENGINEERING JUDGEMENT

Structural capacity indicators are satisfactory; the ZX4 transverse support line and low-load edge bearings trigger yellow warnings.

Assessment basis: measured effects are compared with updated resistance. The report separately flags the transverse measured moment envelope exceeding design and ZX1/ZX4 corner bearings below the AASHTO 20% lower pressure limit.

Longitudinal measured DCR max
37.2%
x=30m · LRFR≈2.69

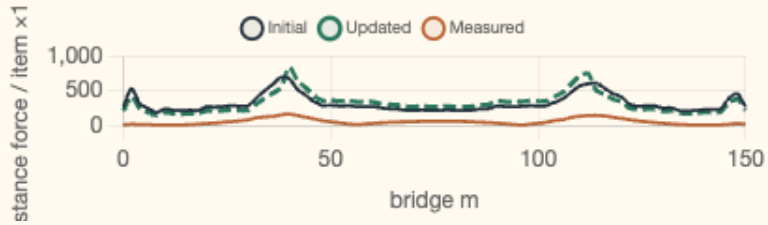
Transverse support-line measured DCR max
45.1%
ZX4 controls · LRFR≈2.22

ZX4 transverse moment exceeds design
+68.5%
measured 17.9 / design 10.6 ×10³ kN·m

Low-pressure warning at edge bearings
4 bearings
ZX1/ZX4 M1 and M3 mean force is 13.6%-18.8% of rated capacity, below the 20% lower limit

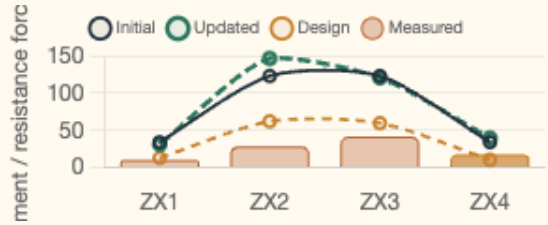
Longitudinal Main-Girder Resistance · Initial vs Updated

Actual resistance updated after EIY correction



Transverse Support-Line Resistance · Initial vs Updated

Actual resistance updated after EIXX correction



1. Capacity indicators

Longitudinal measured DCR is 37.2%; transverse support-line measured DCR is 45.1%; neither reaches a resistance-controlled state.

2. Yellow warning

ZX4 transverse measured moment envelope is about 17.9×10³ kN·m, while the design effect envelope is about 10.6×10³ kN·m, an exceedance of about 68.5%.

3. Low-pressure warning at edge bearings

The four corner bearings ZX1/ZX4 M1 and M3 have mean reactions of 681-938 kN, only 13.6%-18.8% of rated capacity and below the AASHTO 20% lower pressure limit of 1,000 kN.

4. Leveling recommendation

After field recheck, prioritize trial calculation and implementation of +3 to +4 mm jacking at ZX4-M1 or ZX4-M3. Acceptance should be based on transverse moment reduction and recovery of the four corner bearings above the 20% lower limit.

5. Strengthening judgment

The resistance assessment is OK. The above issues should be handled as bearing contact, reaction balancing and local leveling problems; structural strengthening is not recommended.

December Bearing–Elevation Event Closure

From an October–model extrapolation that no longer matched, to a boundary–state update that realigned the prediction after the event. This page is the English appendix for the 77d print report.

v20260514.10–print–event

Report conclusion: around December, the reaction time histories showed a systematic deviation that the baseline model could not explain. After the field bearing–jacking event is back–substituted as a boundary–state change, the independent validation segment realigns clearly. The term settlement here should be read as equivalent elevation change: negative Delta z means relative lowering and positive Delta z means relative lifting. Each inverted Delta z should not be read directly as a construction quantity.

01 Observation

December extrapolation no longer aligns

The baseline model trained in October was extrapolated to December, but several bearing reactions kept drifting away from the prediction. This does not look like isolated noise; it is more consistent with a changed boundary state.

02 Field action

Bearing–jacking window

Field record: a bearing–jacking test was carried out from 2024–12–25 to 2024–12–30. ZX1–M3 and ZX2–M3 were each raised by +2.00 mm.

03 Validation

Post–event prediction realigns

The post–event data are used to update the boundary state, and an independent validation segment checks the result. If the updated curve returns to the measured curve, this is a verifiable event closure rather than a retrospective story.

Validation mean RMSE	Validation time–history RMSE	Update–window time–history RMSE	Event gap
197 → 32 kN	204 → 59 kN	175 → 40 kN	7.8 days
83.9% improvement	71.0% improvement	77.2% improvement	12–24 14:00 to 25–01–01 09:00

Pre–event extrapolation check
12–01 00:00 → 12–24 14:00
322 h · The October baseline state is extrapolated to December to check whether it still explains the measured reactions.

Bearing–jacking window
12–24 14:00 → 25–01–01 09:00
The field action occurred within this window, and the reaction state changes across the window.

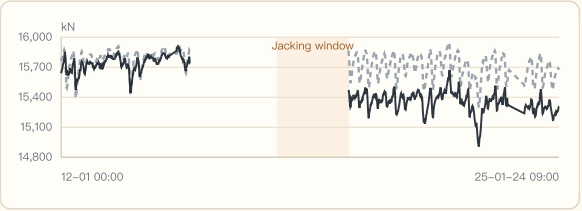
Post–event update segment
25–01–01 09:00 → 25–01–08 09:00
169 h · A short post–event window is used to identify the new boundary state.

Independent validation segment
25–01–08 10:00 → 25–01–24 09:00
346 h · This segment is not used for updating; it checks whether the prediction truly realigns.

1. Before update: baseline prediction only

12–01 00:00 → 25–01–24 09:00 · 838 h · ZX2–M2

Measured Baseline prediction

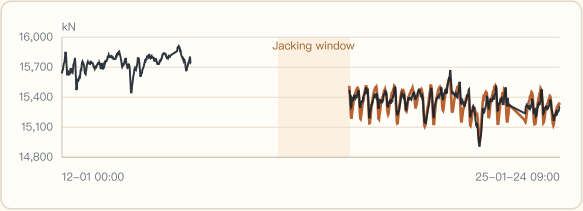


The updated prediction is intentionally not shown here. With only the October baseline extrapolation, the baseline prediction and measured reactions are clearly separated after the December bearing–jacking window.

2. Event capture: updated prediction appears

12–01 00:00 → 25–01–24 09:00 · 838 h · ZX2–M2

Measured Updated prediction



After the event, a new boundary state is introduced. The updated prediction appears only after the jacking window and shows why the later segment realigns.

Elevation Event Comparison · Model–Predicted Change vs Field Change

Field change comes from field facts; model change comes from reaction back–substitution

Bearing	Pre–event elevation	Model–predicted change	Field change	Mean force shift
ZX1–M1	–1.89 mm	+1.24 mm	0	+69 kN
ZX1–M2	+4.22 mm	+0.00 mm	0	–154 kN
ZX1–M3	–2.40 mm	+1.31 mm	+2.00 mm	+86 kN
ZX2–M1	–1.64 mm	+0.77 mm	0	+153 kN
ZX2–M2	+2.87 mm	+0.12 mm	0	–304 kN
ZX2–M3	–1.45 mm	+0.74 mm	+2.00 mm	+148 kN
ZX3–M1	–3.24 mm	+0.20 mm	0	+95 kN
ZX3–M2	+7.72 mm	–0.23 mm	0	–192 kN
ZX3–M3	–3.50 mm	+0.24 mm	0	+99 kN
ZX4–M1	–3.53 mm	–0.04 mm	0	+12 kN
ZX4–M2	+6.21 mm	–0.43 mm	0	–25 kN
ZX4–M3	–3.37 mm	–0.11 mm	0	+12 kN

This table puts what the model says the boundary state should do and what was actually adjusted on site into one evidence chain. The two are not meant to be item–by–item identical, but if the direction and reaction improvement close, they form an event validation.

Data source: 77d_update_event_corrected_reg.json + corrected_reg_model_residual_update_c001 · same basis as the current Chrome event table · generated 2026–05–13T01:39:44.829Z · page version v20260514.10