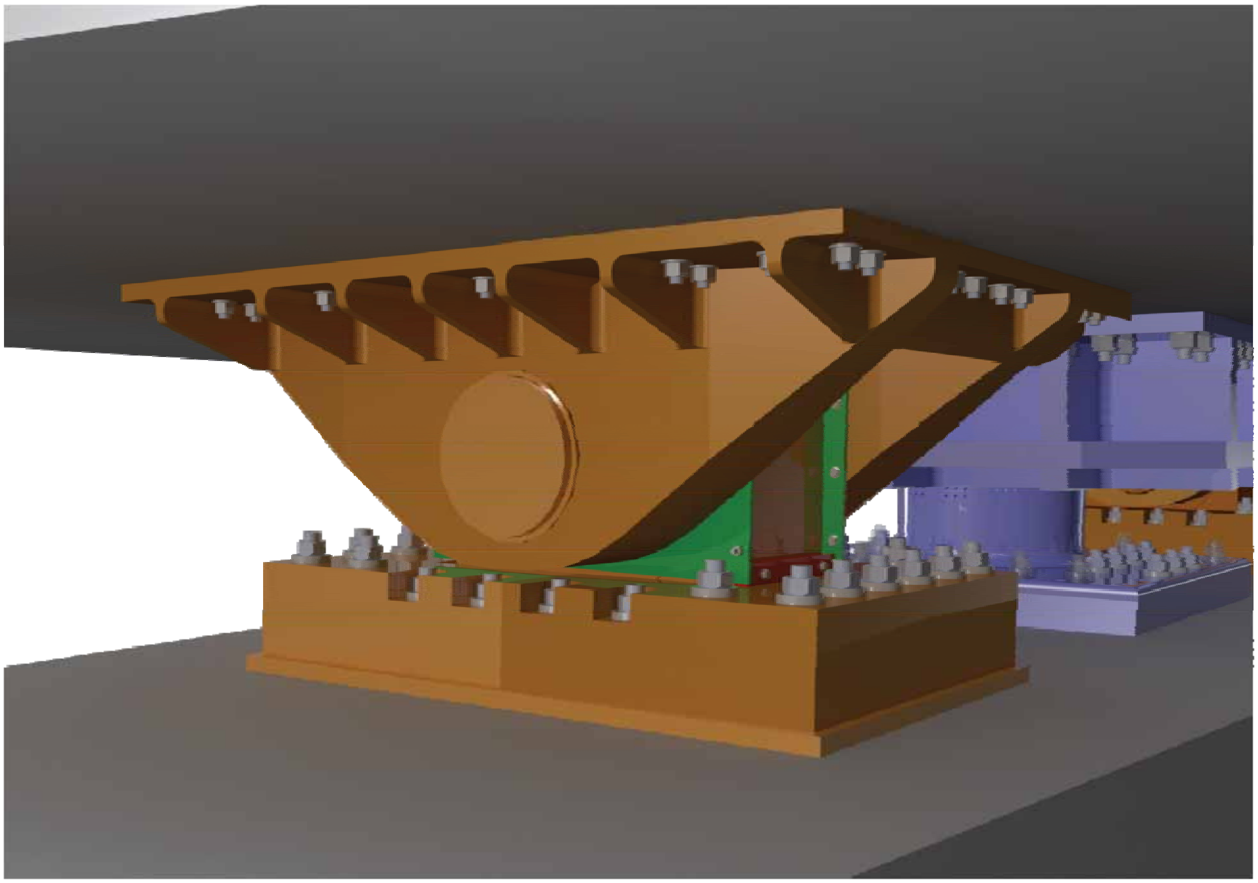
San Francisco-Oakland Bay Bridge

Self-Anchored Suspension Span (SFOBB-SAS)



SEISMIC EVALUATION OF SAS AT E2 PIER PRIOR TO COMPLETION OF SHEAR KEYS S1 & S2

July 15, 2013

T·Y·LIN INTERNATIONAL
MOFFATT & NICHOL ENGINEERS
a joint venture

TABLE OF CONTENTS:

STATEMENT OF PURPOSE:

This report provides a summary of the technical information for the seismic evaluations of the San Francisco-Oakland Bay Bridge (SFOBB) East Spans Self-Anchored Suspension (SAS) at E2 Pier prior to completion of shear keys S1 and S2.

This report documents information on demand and capacity of relevant stages of construction and service. Additionally, visual images are included to support the understanding of various structural elements and staging. Supporting finite element analysis (FEM) is also provided.

This report evaluates temporary bearing modifications by adding simple shims to the Pier E2 Bearings (B1, B2, B3 and B4) to engage the bearing's reserve capacities for an interim condition.

EXECUTIVE SUMMARY:

As requested by Caltrans and as presented and discussed during the Seismic Safety Peer Review Panel (SSPRP) meeting with Caltrans and the peer review panel on July 3 2013, the Design Joint Venture of T.Y. Lin International / Moffatt & Nichol Engineers have performed an evaluation of the seismic capacity of the shear keys and bearings at Pier E2 of the Self-Anchored Suspension (SAS) Bridge. To this end various alternative load paths were evaluated and compared against the Seismic Demands for the Design Level Earthquake per the Project Specific Design Criteria. These Seismic Demands correspond to the envelope of the maximum time-history analysis response from six different 1500-year ground motions (SEE - Safety Evaluation Earthquake). At the top of Pier E2, these SEE demands total 50MN in the longitudinal direction of the bridge and 120MN in the transverse direction of the bridge.

The design lateral capacity of the shear keys and bearings at Pier E2 can be summarized as follows:

	Longitudinal Direction	Transverse Direction
- Shear Keys S1 & S2:	42 MN	42 MN
- Shear Keys S3 & S4:	42 MN (20mm Gap)	42 MN
- Bearings B1, B2, B3 & B4:	15 MN (20 mm Gap)	30 MN (20 mm Gap)

The design plans account for two alternative load paths:

A) Load Path A (shear keys are engaged) – This load path maintains the 20 mm gaps in S3 & S4 and the Bearings B1, B2, B3 & B4, thereby engaging only shear keys S1 & S2 in both directions and S3 & S4 in the transverse direction only. This provides a total capacity of 84 MN and 168 MN in the longitudinal and transverse directions, respectively.

B) Load Path B (all shear keys discounted) – This load path engages the Bearings B1, B2, B3 & B4 in both directions upon closing of the 20 mm gap due to seismic movement. This provides a total capacity of 60 MN and 120 MN in the longitudinal and transverse directions, respectively.

Assuming that the New Design of the Shear Keys S1 & S2 is not completed and by implementing interim shimming of the Bearings B1, B2, B3 & B4 to close the 20 mm gaps, a third alternative load path to resist the design lateral SEE demands can be developed: (reference Plan Sheet 883S1/1204 “Pier E2 Details No. 1A)

C) Load Path C (shear keys S1 & S2 discounted) – This load path engages the Bearings B1, B2, B3 & B4 by interim shimming of the 20 mm gaps in both directions, in addition to S3 & S4 being engaged in the transverse direction only. This provides a total capacity of 60 MN and 204 MN in the longitudinal and transverse directions, respectively.

The table in the Evaluation of Alternative Load Path at Pier E2 section provides a summary of the Seismic Lateral Capacity at Pier E2 for Load Path A, B & C, the SEE demands, and the associated Factors of Safety.

Enclosed please find a rendering depicting the installation sequence of the shims as well as a Finite Element Analysis (FEM) of the bearings.

BRIAN MARONEY'S (CALTRANS) MEMO:

(FROM EMAIL DATED JUNE 29, 2013 TO PMT / TBPOC / SSPRP)

This memo is to briefly summarize the safety of the Self-Anchored-Suspension bridge segment with respect to the expected performance of the San Francisco-Oakland Bay Bridge during a design level earthquake assuming the S1 and S2 shear key work currently underway is not fully completed by the time of seismic safety opening. In simplified terms, the bridge system between the orthotropic box girder superstructure and the concrete Pier E2 bentcap has enough strength capacity to carry 1500 year return period design level earthquake motion generated shear forces, overwhelmingly driving a shift of public traffic to the replacement bridge from the old bridge based on a desire for public safety.

The bridge capacity to carry the demand loads at Pier E2 is overdesigned to 140% of the worst of six different 1500 year return period earthquake time-history generated loads. The design criteria of the East Spans of the Bay Bridge is based upon 1500 year return period motions, which excides the national standards of 1000 year return period motions. This can be read as there is a 40% extra capacity in the "as-designed" system at Pier E2 above the lifeline criteria that is above the national standard. In simple terms, the system at Pier E2 was not designed to the bare minimum and there was a significant reserve capacity incorporated into the design that we should recognize at this time as leaders consider opening day alternatives. This extra design reserve is important to recognize when accounting for the fact that in construction there has developed a temporary reduction in capacity due to the Pier E2 threaded rod problem. The temporary reduction in strength capacity of the Pier E2 system due to the 2008 rod fractures is less than the overdesign. Therefore, leadership can advance increase public safety by opening the bridge as soon as feasible.

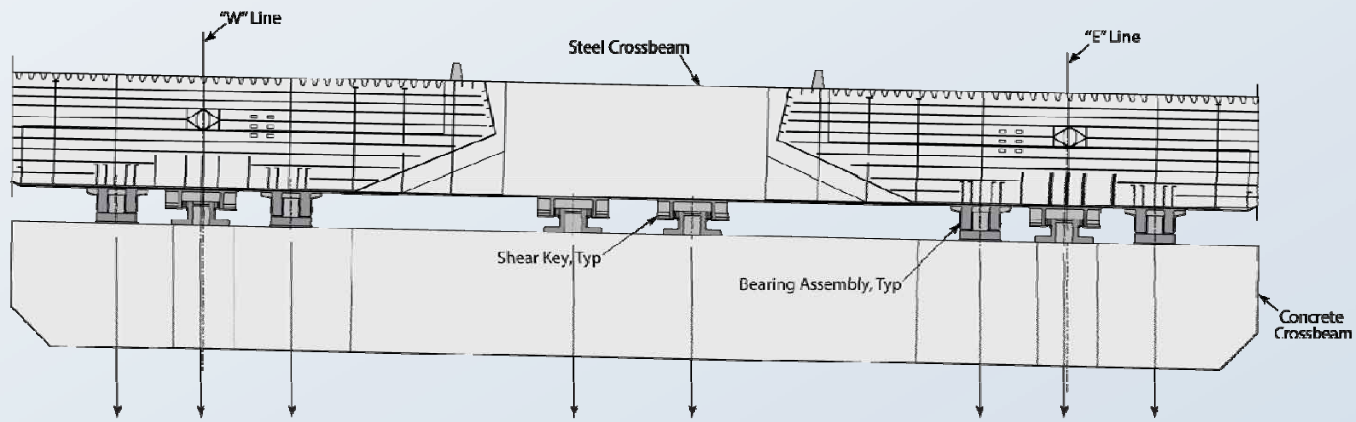
From bridge computer demand analysis models, earthquake lateral demands at the top of Pier E2 can be very simply summarized as 120 MN of force transversely and 50 MN of force longitudinally. If it is conservatively assumed that the S1 and S2 shear keys are completely ineffective, the S3 and S4 shear keys are only effective in the transverse direction and the B1, B2, B3 and B4 bearings are temporarily shimmed to engage them at zero relative displacement, lateral capacity to carry the 120 MN lateral demand is estimated at [2 * (42) + 4 * (30)] = 204 MN. Clearly, 204 MN is greater than 120 MN. Similarly, in the longitudinal direction the four shimmed bearings provide a capacity of [4 * (15)] = 60 MN and 60 MN is greater than 50 MN. These simple calculations demonstrate the new bridge provides well-above standard seismic safety even if the S1 and S2 shear key work is not complete.

The existing bridge was not designed for the most basic "no-collapse" seismic safety criteria that is typically employed in modern bridge design. The old bridge is at risk in large Bay Area earthquakes as was demonstrated during the 1989 Loma Prieta Earthquake. The modest interim retrofit was developed to address the most fundamental seismic risks up to a limit of 25 million dollars. It was a good investment but was never intended to address long-term seismic risks associated with even a standard of 1000 year return period "no-collapse" criteria.

This summarizing discussion demonstrates that the San Francisco – Oakland Bay Bridge East Spans Replacement Structure offers significantly superior seismic safety to the public compared to the old bridge. From a technical perspective, it can be relatively easily concluded that the public should be moved onto the new structure at the first practical opportunity even if the S1 and S2 shear key work is not complete. It should be clear that the S1-S2 work is valuable as it provides the level of extra safety, reliability and toughness that was envisioned in the original design by bridge earthquake specialists and should be completed on an expedited schedule.

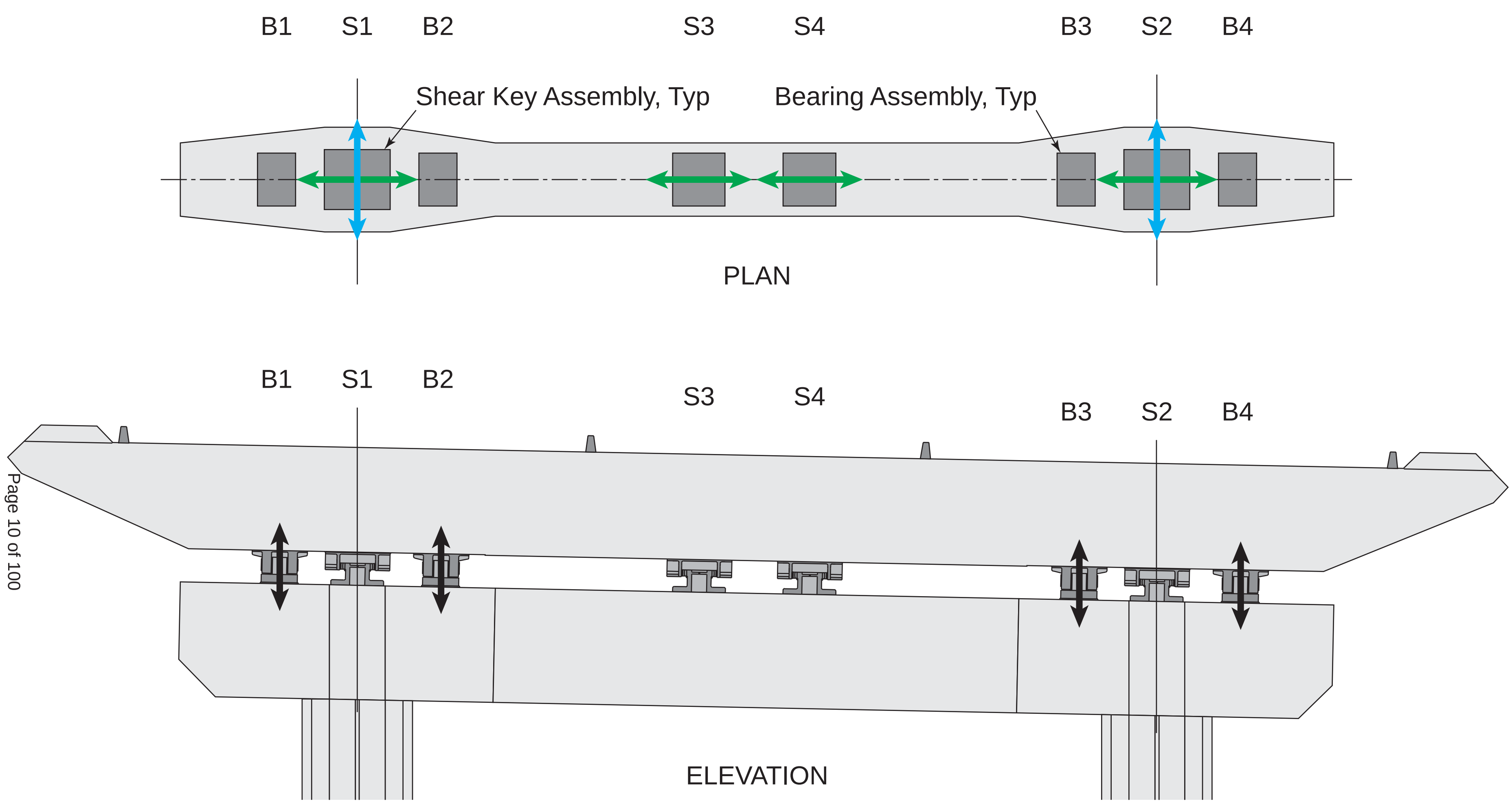
Evaluation of Alternative Load Path at Pier E2

EVALUATION OF ALTERNATIVE LOAD PATHS AT PIER E2 FOR SEISMIC RESISTANCE



		Direction	B1	S1	B2	S3	S4	B3	S2	B4	TOTAL (MN)	SAFETY FACTOR
DEMAND	SEISMIC DEMAND FOR SEISMIC SAFETY EVALUATION (SEE) EARHQUAKE	Long									50	
		Trans									120	
CAPACITY	LOAD PATH A: (ALL SHEAR KEYS ENGAGED)	Long	0[(a)]	42	0[(a)]	0[(c)]	0[(c)]	0[(a)]	42	0[(a)]	84	168%
		Trans	0[(b)]	42	0[(b)]	42	42	0[(b)]	42	0[(b)]	168	140%
	LOAD PATH B: (ALL SHEAR KEYS DISCOUNTED) (BEARINGS ENGANGED)	Long	15	0	15	0	0	15	0	15	60	120%
		Trans	30	0	30	0	0	30	0	30	120	100%
	LOAD PATH C: (INTERIM SHIM OF BEARINGS) (S1 & S2 SHEAR KEYS DISCOUNTED)	Long	15	0	15	0[(c)]	0[(c)]	15	0	15	60	120%
		Trans	30	0	30	42	42	30	0	30	204	170%

a. 30 mm gap in the longitudinal direction. Bearing (B1, B2, B3, and B4) engage after 30 mm gap is closed by displacement.
b. 20 mm gap in the transverse direction. Bearing (B1, B2, B3, and B4) engage after 20 mm gap is closed by displacement.
c. 43 mm gap filled with neoprene open cell. Shear Keys (S3 and S4) engage in the longitudinal direction after 43 mm gap is closed by displacement.

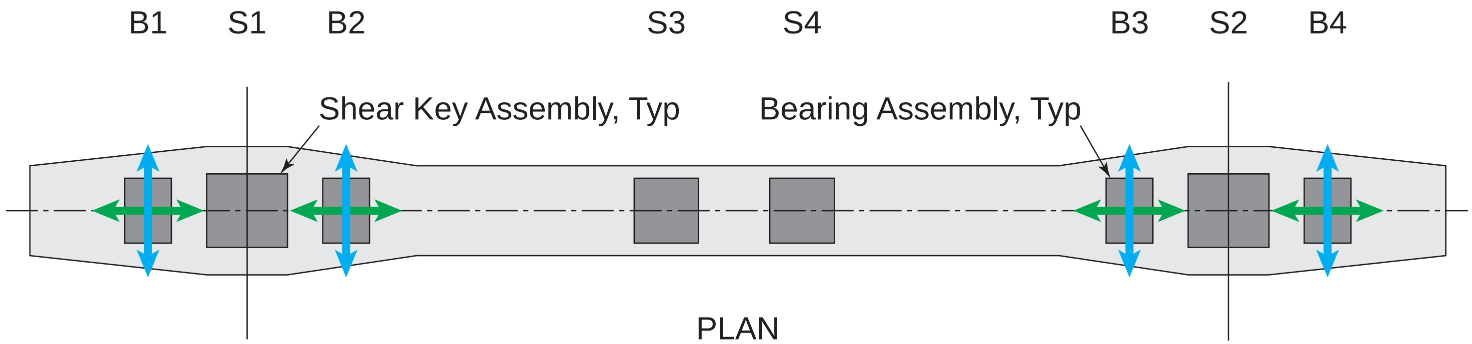


LOAD PATH A — ALL SHEAR KEYS ENGAGED

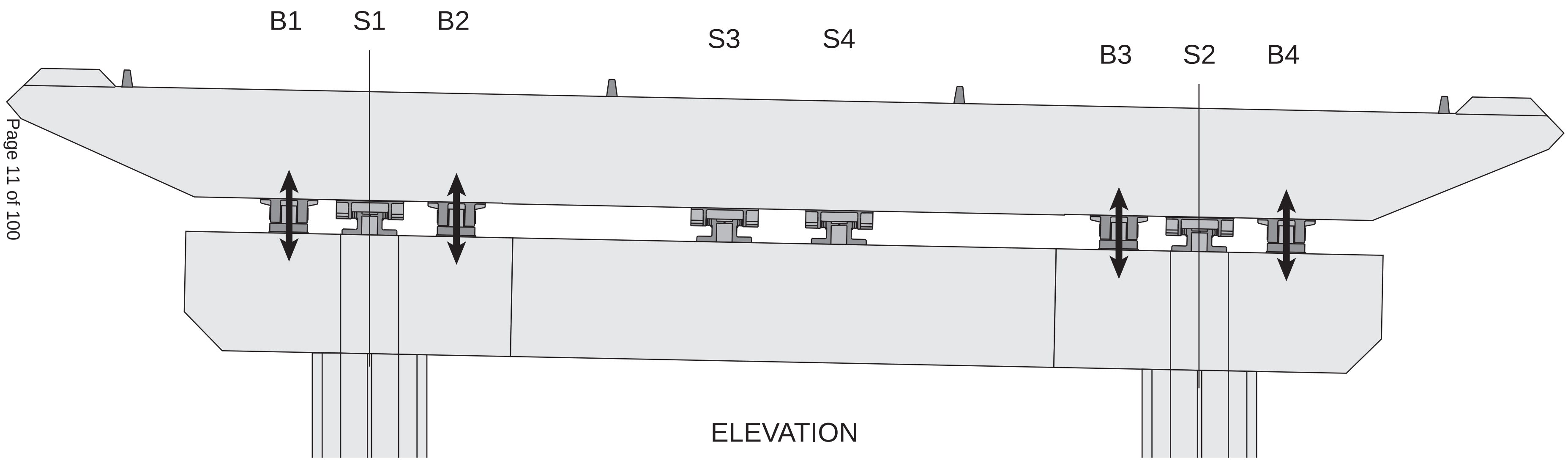
(Force Resistance Of Shear Keys And Bearings)

Direction of applied force that element can resist:

- Uplift
- Transverse
- Longitudinal



PLAN



ELEVATION

LOAD PATH B — ALL SHEAR KEYS DISCOUNTED / ALL BEARINGS ENGAGED

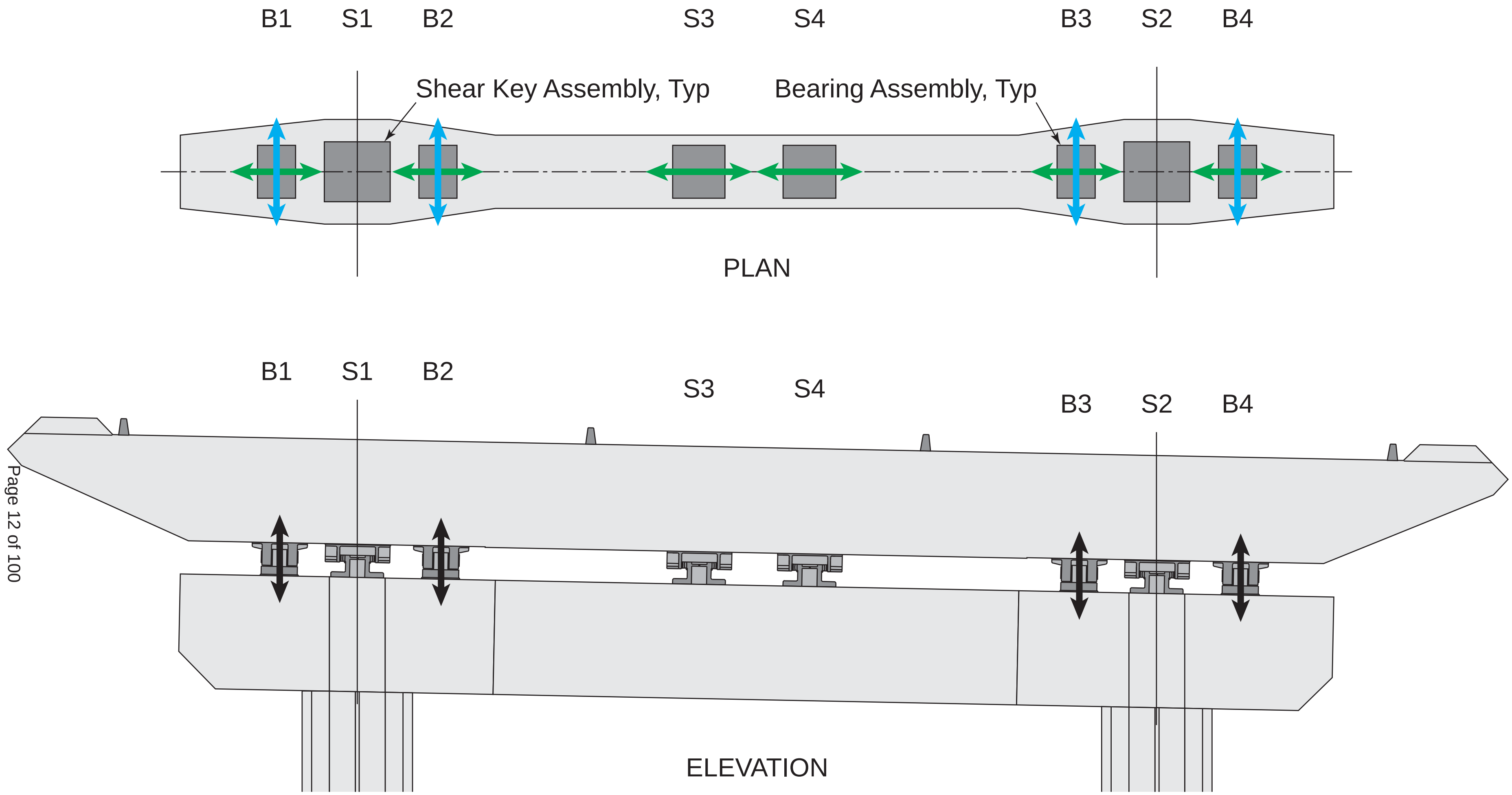
(Force Resistance Of Shear Keys And Bearings)

Direction of applied force that element can resist:

Uplift

Transverse

Longitudinal



LOAD PATH C — INTERIM SHIMMING OF BEARINGS / S1 & S2 SHEAR KEY DISCOUNTED

(Force Resistance Of Shear Keys And Bearings)

Direction of applied force that element can resist:

Uplift

Transverse

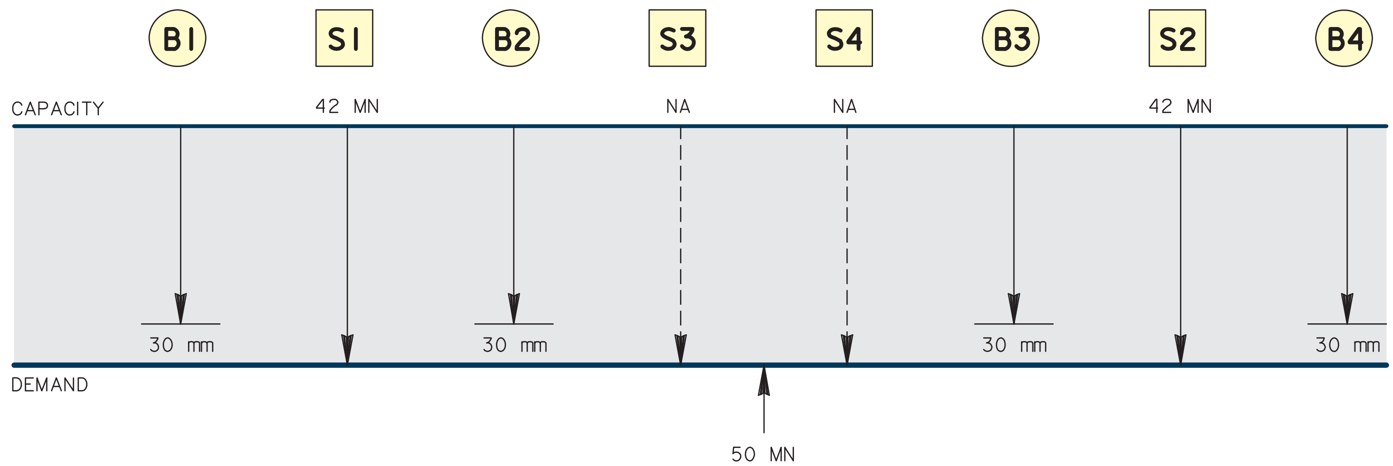
Longitudinal

LONGITUDINAL

(DEMANDS & CAPACITIES)

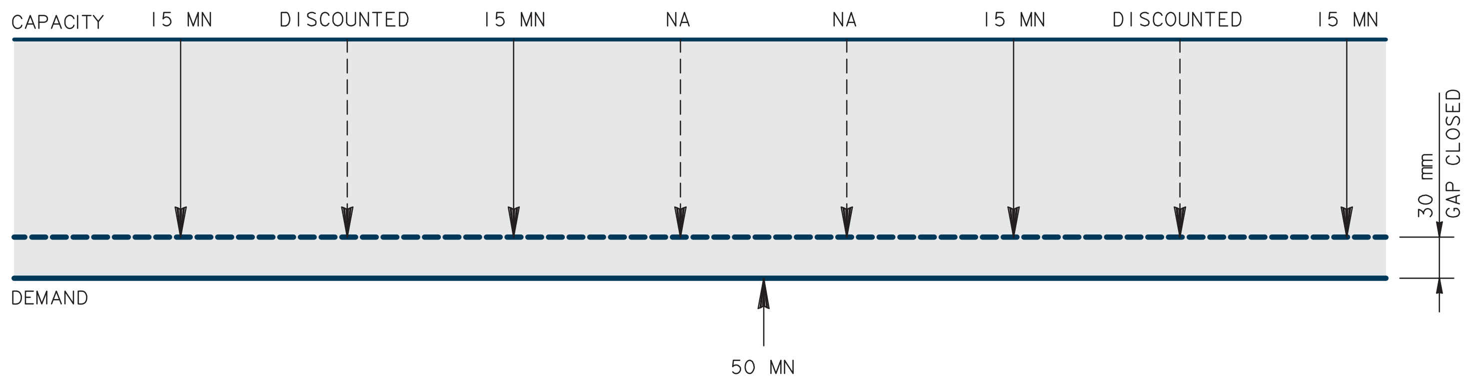
LOAD PATH (A)

- AS DESIGNED NOMINAL



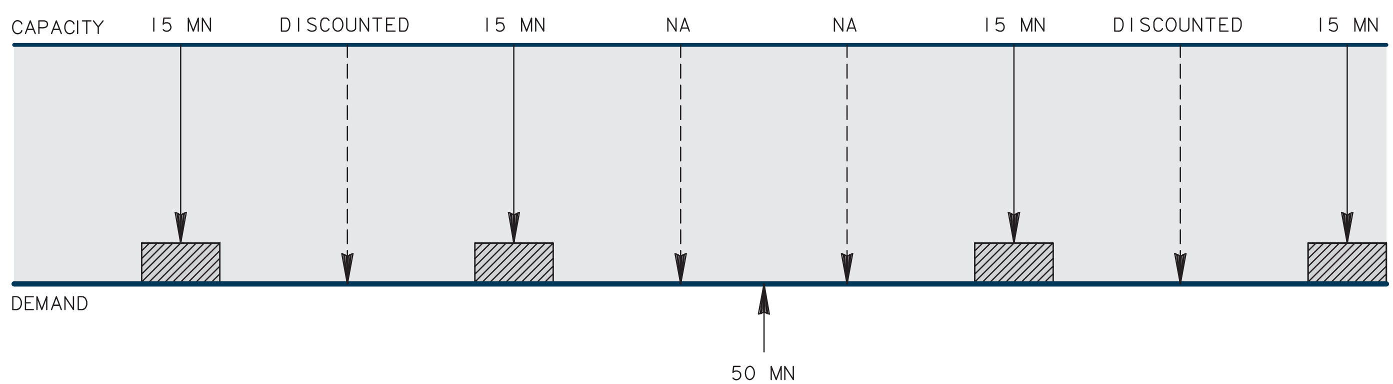
LOAD PATH (B)

- AS DESIGNED GAP CLOSED
- S1, S2 DISCOUNTED
- S3, S4 NOT ENGAGED



LOAD PATH (C)

- INTERIM FIX
- GAP CLOSED BY SHIMMING
- S1, S2 DISCOUNTED
- S3, S4 NOT ENGAGED



TRANSVERSE

(DEMANDS & CAPACITIES)

LOAD PATH (A)

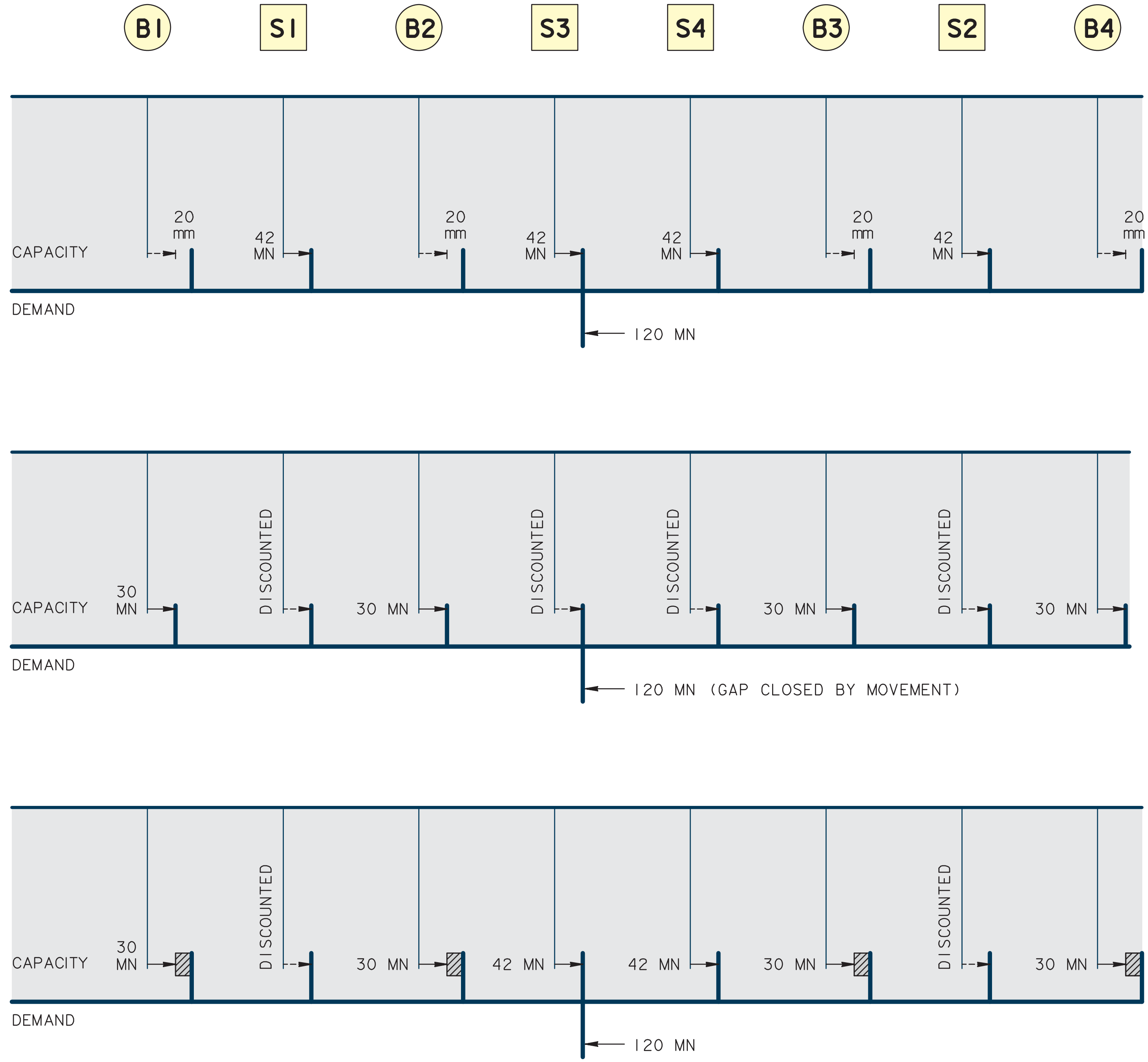
– AS DESIGNED NOMINAL

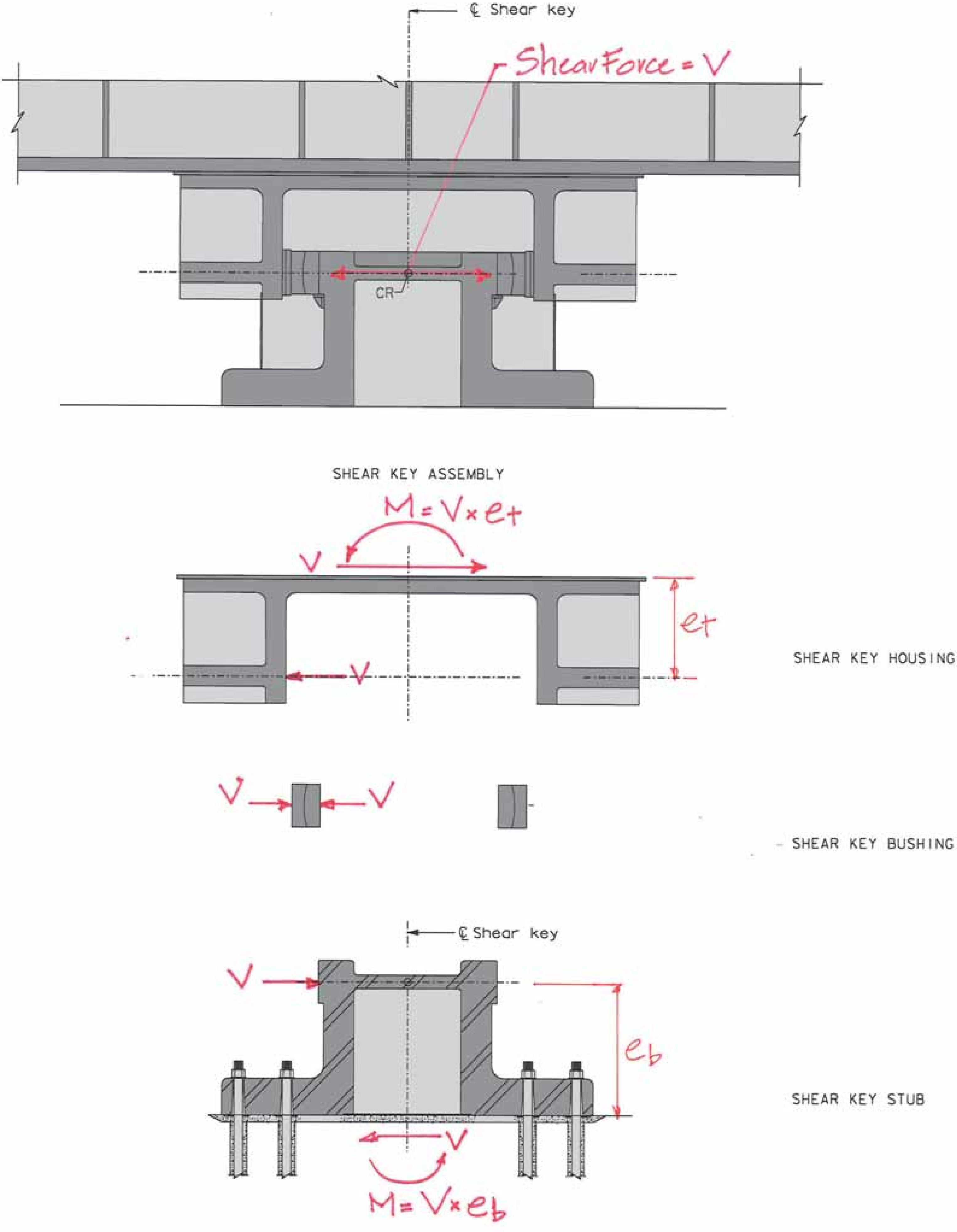
LOAD PATH (B)

– AS DESIGNED GAP CLOSED
– S1, S2, S3 & S4 DISCOUNTED

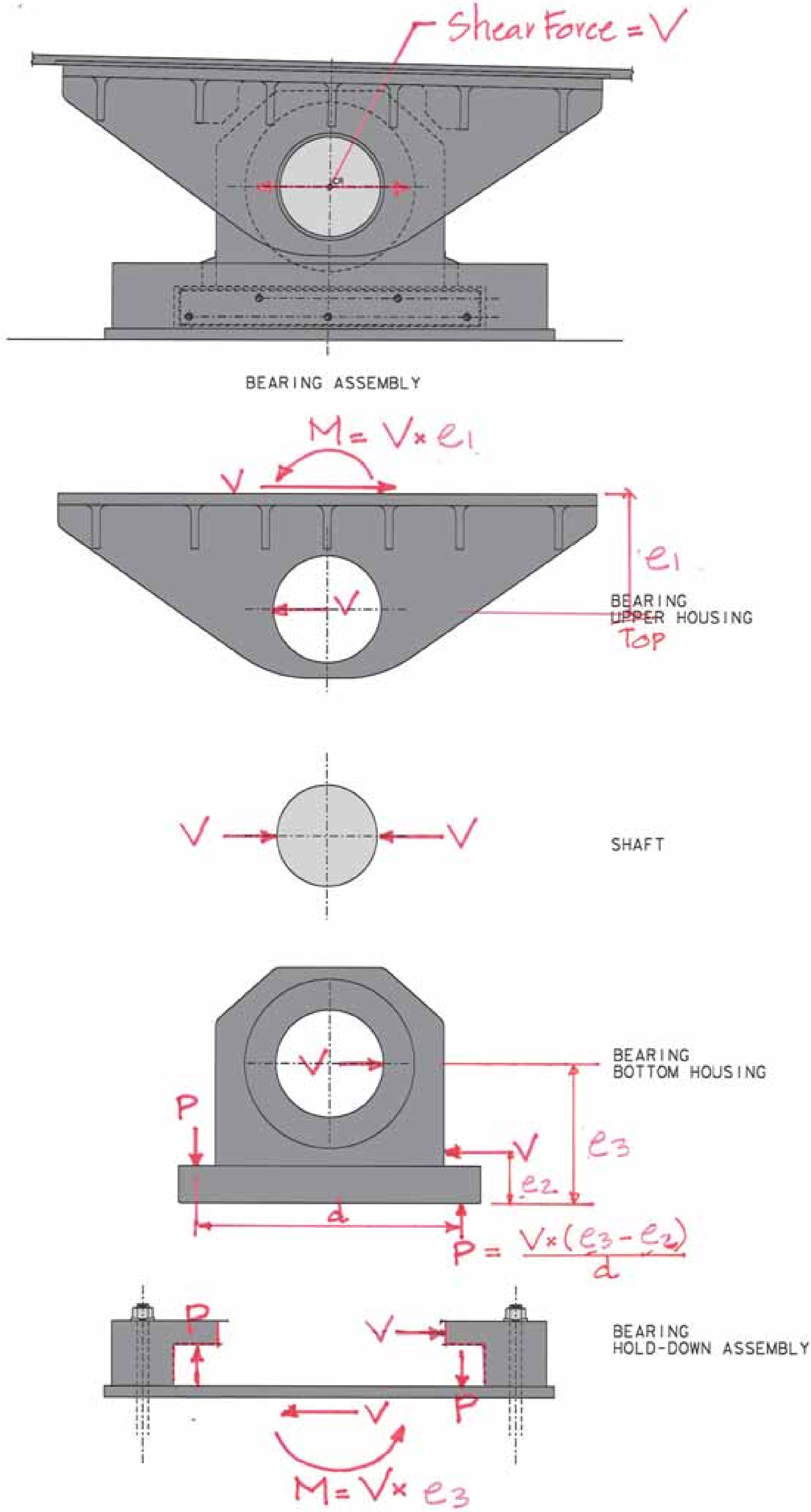
LOAD PATH (C)

– INTERIM FIX
– GAP CLOSED BY SHIMMING
– S1, S2 DISCOUNTED

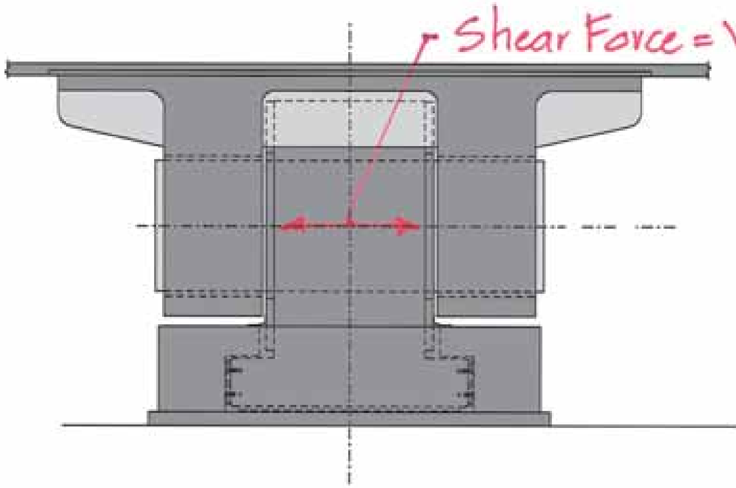


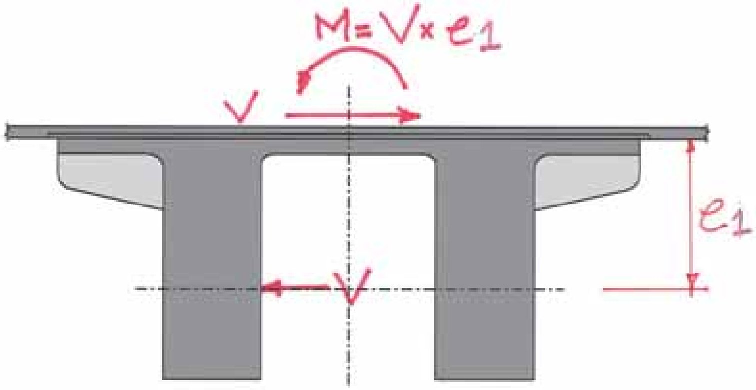


LOAD THROUGH SHEAR KEY

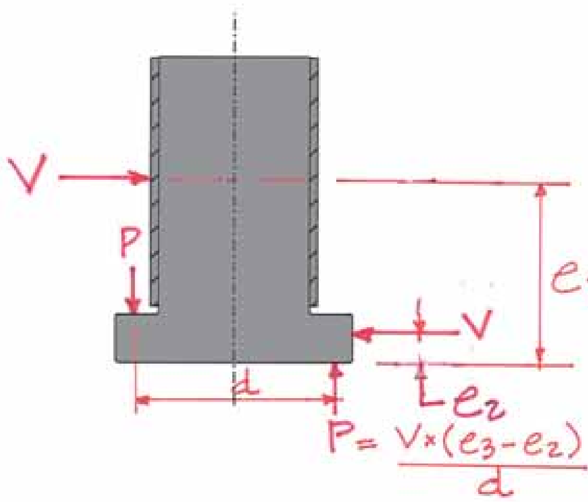


LOAD THROUGH BEARING – LONGITUDINAL SHEAR

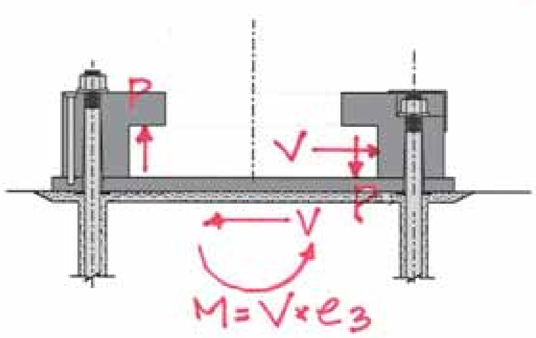




BEARING TOP HOUSING

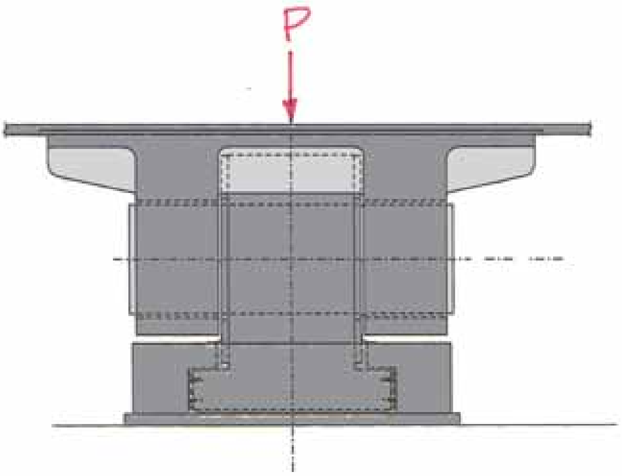


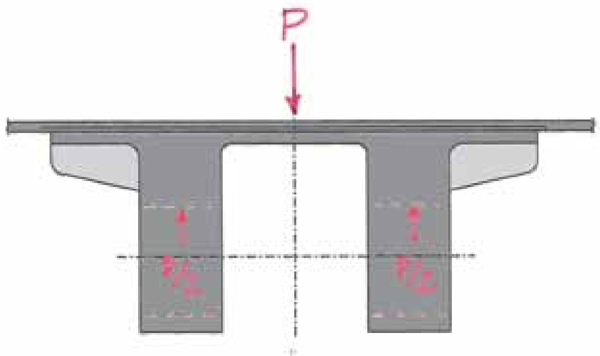
BEARING BOTTOM HOUSING



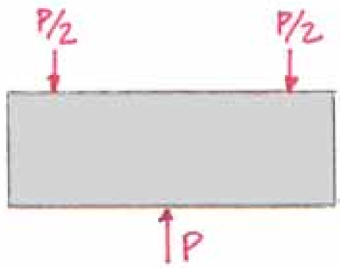
BEARING HOLD-DOWN ASSEMBLY

LOAD THROUGH BEARING – TRANSVERSE SHEAR

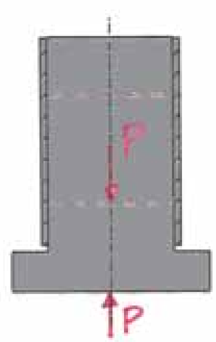




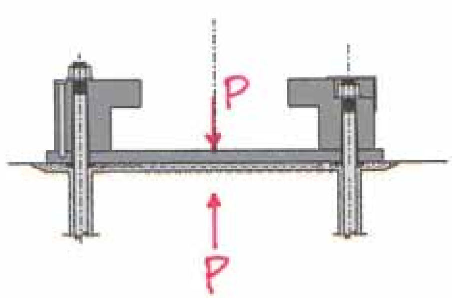
BEARING TOP HOUSING



SHAFT

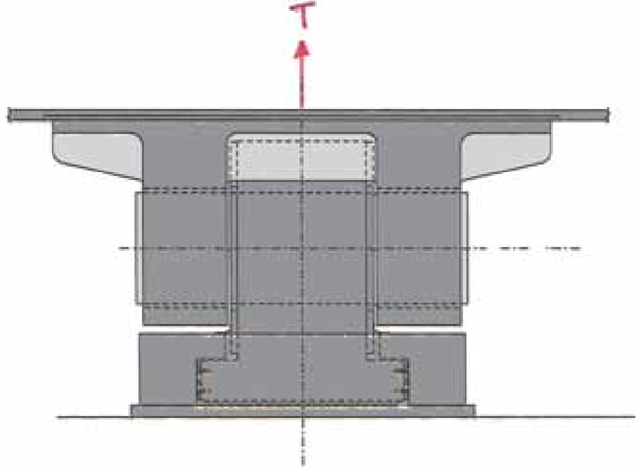


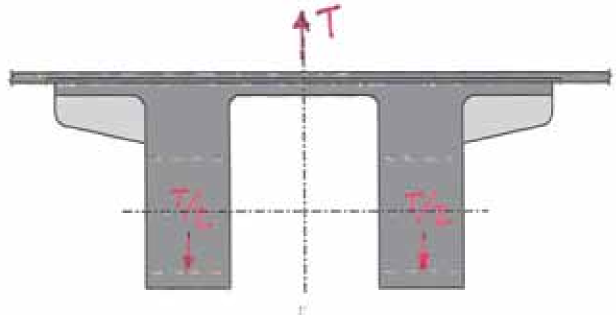
BEARING BOTTOM HOUSING



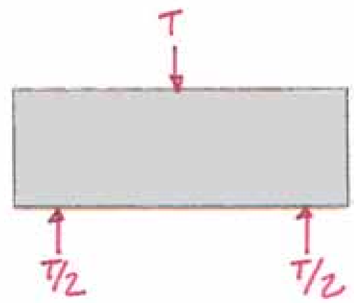
BEARING HOLD-DOWN ASSEMBLY

LOAD THROUGH BEARING – COMPRESSION

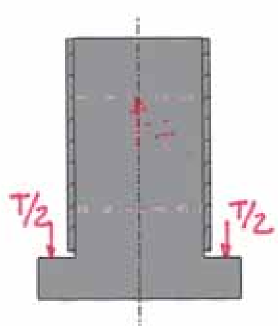




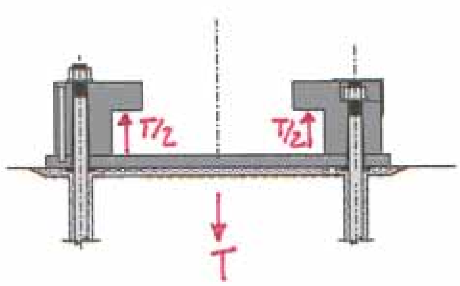
BEARING TOP HOUSING



SHAFT



BEARING BOTTOM HOUSING



BEARING HOLD-DOWN ASSEMBLY

LOAD THROUGH BEARING - UPLIFT

CCO No. 331 – E2 Bearing Shimming Details (883S1 of 1204)

DIST.	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	SF	80	13.2/13.9	883SI	1204

REGISTERED ENGINEER - CIVIL
07-03-13
PLANS APPROVAL DATE

PROFESSIONAL ENGINEER · REGISTERED · Marwan N. Nader · No. C 054426 · Exp. 12/31/13 · CIVIL · STATE OF CALIFORNIA

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T.Y. LIN / MOFFATT & NICHOL
825 BATTERY STREET
SAN FRANCISCO, CA 94111

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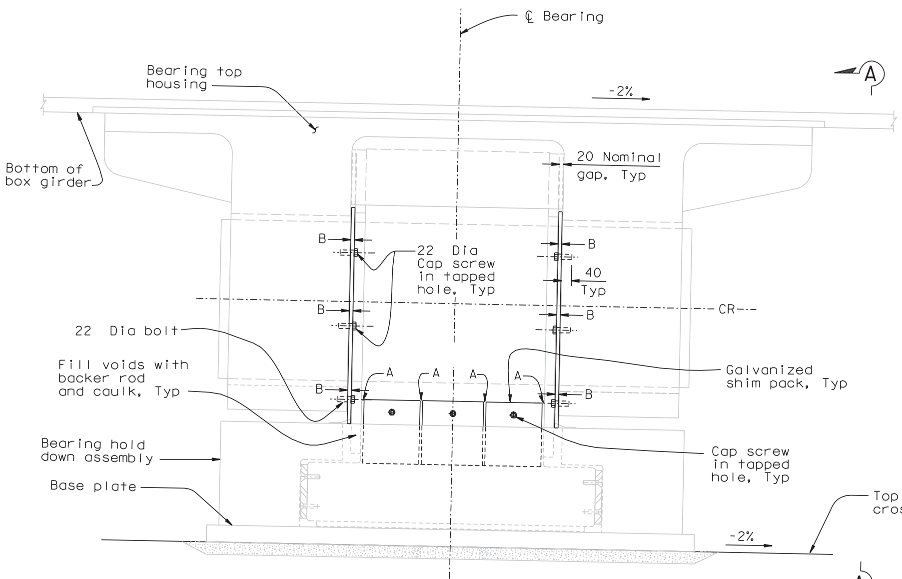
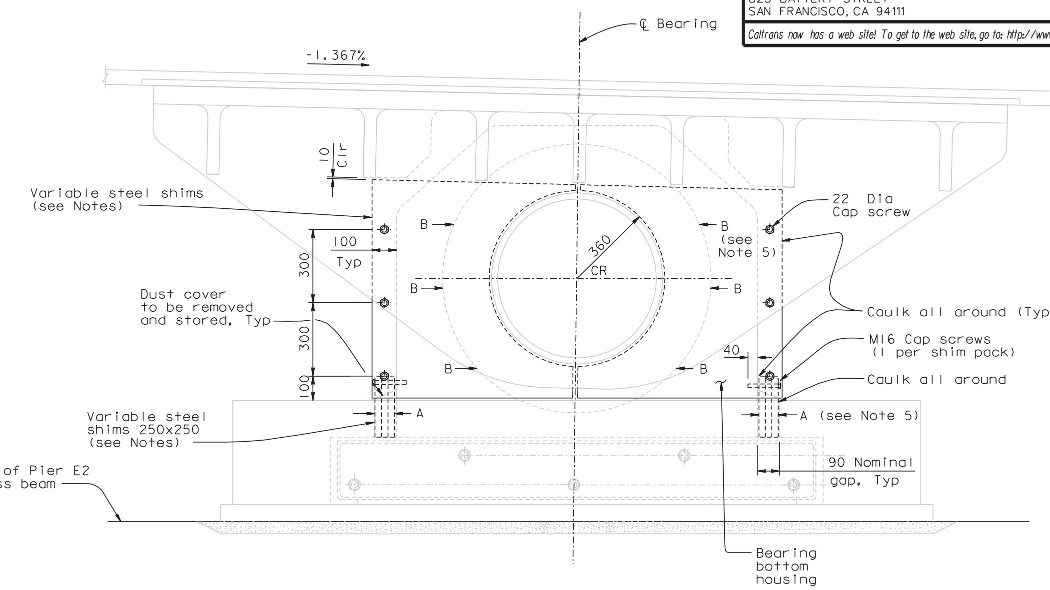


DETAIL OF BEARING ASSEMBLY
1:10



VIEW A-A
1:10

INSTALLATION SEQUENCE FOR BEARING SHIMS:

NOTE: Shimming shall be completed prior to SSO.

1. On one OBG (EB or WB), install longitudinal and transverse shimming on both bearings.
2. On the same OBG and for one temporary bearing at a time, transfer the load to the permanent bearing and remove temporary bearing shimming. Repeat for both temporary bearings.
3. Repeat Steps 1 & 2 for the remaining OBG.

NOTES:

1. Shims shall be galvanized.
2. Each shim shall be PTFE coated on one side.
3. Provide for each shim pack 4 shims tapered at 1/40 maximum, as required per survey.
4. Shim tight to within 2 mm, total of all plies.
5. Variable shims shall be fabricated and provided based on field measurements of gaps in the bearing assembly. Gap "A" in the lower housing is 90 mm nominal. Gap "B" in the upper housing is 20 mm nominal.

E2 BEARING SHIMMING

CONTRACT CHANGE ORDER NO. ____
SHEET ____ OF ____

REQUESTS FOR INFORMATION NOT ADDRESSED IN THIS CCO REMAIN IN FORCE

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN

MARK	DATE	DESCRIPTIONS	BY	CH'D	CCO#
1	07/03/13	SHIMMING OF E2 BEARINGS	GB	MN	331

REVISIONS

A. Akinsanya / W. Long
DESIGN OVERSIGHT
SIGN OFF DATE 07/03/13

	BY	CHECKED
DESIGN	G. Baker	N. Vo
DETAILS	G. Baker	N. Vo
QUANTITIES	G. Baker	N. Vo

PREPARED FOR THE STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

M. Nader
PROJECT ENGINEER

BRIDGE NO. 34-0006L/R
KILOMETER POST 13.2/13.9

SAN FRANCISCO OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT
SELF-ANCHORED SUSPENSION BRIDGE
(SUPERSTRUCTURE & TOWER)

PIER E2 BEARING DETAILS NO. 1A

Rev. Date: 5-18-98
ORIGINAL SCALE IN MILLIMETERS FOR REDUCED PLANS 0 10 20 30 40 50 60 70 80 90 100
CU 04
EA 0120F1
DISREGARD PRINTS BEARING EARLIER REVISION DATES
REVISION DATES (PRELIMINARY STAGE ONLY) 07/03/13
SHEET 466SI OF

FILE => L:\BB\04-0120F1\SAS\Contract Plans and CCO\CCO\CCO#331\1-Original 07-01-13\DGN\akbrg01a.dgn

USERNAME => orivera DATE PLOTTED => 03 JUL 2013 TIME PLOTTED => 18:19:03

100 % PS&E

Shim Installation Sequence