FINAL REPORT

RECESSED FLOATING PIER CAPS FOR HIGHWAY BRIDGES

by

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Consultant to the Virginia Highway Research Council

Virginia Highway Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways and the University of Virginia)

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SUMMARY

Presented are alternate designs for two existing bridges in Virginia — one with steel beams and the other with prestressed concrete beams — whereby the pier caps are recessed within the depth of the longitudinal beams. The purpose of this recession is to provide cleaner aesthetic lines for these bridges. At the same time, the recessed caps (transverse girders) are designed to "float" or slide on TFE bearings fixed to the tops of the piers. This arrangement allows the number of bearings needed to be greatly reduced.

Design calculations and drawings prepared for each bridge permit an economic comparison to be made between the original designs and the modified designs. The conclusion reached is that the alternate design is completely feasible for the steel bridge; but for the concrete bridge, the alternate design would be more expensive.

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INTRODUCTION

Following the direction set forth in the Working Plan "Recessed Floating Pier Caps for Highway Bridges", dated January 1973, a study was made of ways to recess bridge pier caps into the depth of the superstructure itself. At the same time, the recessed pier cap was designed to "float" or slide on the tops of the piers to accommodate thermal or load related movements. The advantages of these innovations are as follows:

1. The esthetic lines of the bridge are improved.
2. Fewer expansion joints are required in the deck, which reduce cost and maintenance problems.
3. Fewer bearing assemblies are needed, which possibly reduce cost and maintenance problems.
4. The pier caps, along with the stringer beams (both in steel and concrete), can be prefabricated so as to reduce field erection time.

STUDY STRUCTURES

For direct comparison, two recent bridges already designed and built in the conventional manner were selected for redesign using recessed pier caps. The first bridge is a three-span steel girder structure on Rte. 631 over the Southern Railroad in Albmarle County. The total length of this bridge is 152'-5½". The original design was done by the Virginia Highway Department bridge division in 1970-71. The bearing systems for this bridge consist of a combination of laminated neoprene bearing pads and steel rocker plates. The second bridge is a four-span precast-prestressed concrete girder structure on Rte. 19 over the Norfolk and Western railroad in Tazewell County. This bridge is 222'-2½" in overall length and was designed by Harrington and Cortelyon, consulting engineers, in 1970-71. Bearings for this bridge consist of plain neoprene bearing pads.

In both bridges, the longitudinal beams are simply supported and rest on top of cast-in-place reinforced concrete pier caps, except at the ends, where they rest on solid concrete abutments. Each pier cap in turn rests monolithically on three circular piers, spaced so that the ends of the pier cap overhang the outside piers a few feet.

REDESIGNS

Selection of Bearings

As the features of the bearings of the proposed redesigned structures are crucial to the economics of the recessed system, an extensive investigation was first made into both current and new bearing devices. Examined were steel rocker systems, self-lubricating metal bearings, laminated rubber pads, neoprene pads (both plain and laminated) and polytetrafluoroethylene (abbreviated as TFE and trade named Teflon) sliding systems.

For the two bridges under study, cost and the simplicity of design led to the selection of a system utilizing a TFE sliding surface bonded to a laminated rubber pad to accommodate rotational movements. (It is possible that under competitive bidding a similar system using a TFE sliding surface bonded to a neoprene pad would be equally economical.) However, for purpose of this design, "Fabreeka"[1] bearings are shown on the drawings attached. "Fabreeka" bearings, although not currently used for bridge bearings in Virginia, have been used on numerous bridges and structures in other states with satisfactory performance.

Redesign of Steel Bridge (Summary)

The values used for the redesign of the steel bridge are based on references 1-3.

Loads considered — HS20-44 uniform lane loading

Concentrated shear load of 26 kips per lane
Impact on live load
Reduction of live load for multiple lanes
Dead loads of slab, beams, parapet, etc.
Extra dead load on slab of 15 psf.

Computed maximum longitudinal beam reactions (as simple spans)

Interior beams, 76.6 kips
Exterior beams, 72.6 kips
(Beam size unchanged from original design.)

Computed maximum transverse girder reactions (as continuous member)

(Pier positions unchanged from original design.)
Interior support, 238.2 kips
Exterior supports, 255.9 kips

Computed maximum shear in transverse girder (at exterior support), 145.2 kips

Computed maximum movements in transverse girder

Positive moment, 233.9 kips ft. (9.625' from center)
Negative moment, 471.9 kips ft. (over exterior support)

Using M183(A36) steel, required girder size is W33 x 188.

Drawings (sheets 1-3) show those details and features of the superstructure which differ from those of the original bridge. Sheet 4 shows how the pier would be modified by the removal of the concrete caps. Note that in order to compensate for the extra lateral stability provided by the cap, the footing is enlarged and transverse struts are added slightly below grade level between the piers.

Redesign of Concrete Bridge
(Summary)

The values used for the redesign of the concrete bridge are based on references 1-4.

Loads considered — HS20-44 uniform lane loading

Concentrated shear load of 26 kips per lane
Impact on live load
Reduction of live load for multiple lanes
Dead loads of slab, beams, girder, parapet, etc.
Extra dead load on slab of 15 psf

Computed maximum longitudinal beam reactions (as simple spans) acting on the transverse girder

Interior position, 150 kips
Exterior positions, 108 kips
(Beam size unchanged from original design)

Computed maximum transverse girder reactions (as continuous member), including the self-weight of the girder

Interior support, 523 kips
Exterior supports, 238 kips

Computed maximum shear in transverse girder (at interior support), 193.5 kips

Computed maximum moments in transverse girder

Positive moment, 531 kips ft. (13 ft. from center)
Negative moment, 840 kips ft. (at center).

Using an ultimate strength of 6,800 psi for the concrete and 250,000 psi ultimate stress for the tendons, a girder size of 18" x 45" is acceptable for conditions of prestress, shear, and moment loading.

The design of "Fabreeka" bearings is in accordance with reference 3, assuming end rotations of 0.010 radians.

The hanger design is based on the use of 50,000 psi yield stress steel as M161 or M222. The shear and moment acting on the end of the hanger is assumed resisted by the six anchor rods extending into the beam. (The outer first four act in tension, and the inner two act in compression.)

Drawings (sheets 5-8) show those details and features of the bridge which differ from those of the original bridge.

CONCLUSIONS

As presented in the Introduction, the purpose of redesigning the pier caps is four-fold; improvement of the esthetics, reduction of the number of expansion joints in the deck, reduction of the number of bearing assemblies, and prefabrication of the cap member. In examining each of the redesigned bridges, the following conclusions can be drawn.

A — Steel Bridge

1. Esthetics

A view of the exterior elevation shows only the stub of the transverse girder as the only portion of the "pier caps" visible. With a modification of the exterior connection between the beam and the girder, even this stub could be removed. However, as such a connection would be more expensive (due to the eccentricities introduced) it was decided to recommend the detail as shown.

2. Deck Joints

The original bridge requires 4 transverse joints in the deck, one at each support, to accommodate the expansion and contraction at these positions. The proposed design requires only two transverse joints, one immovable and one movable. The movable joint for this length of bridge need accommodate only 1-7/8 inches of movement, so a relatively simple joint is all that is needed. For this design, a commercially available steel laminated neoprene joint manufactured by the General Tire & Rubber Co. (trade named Transflex) is suggested. Other types of joints are also possible.

3. Bearings

The original design requires 30 separate bearings, whereas the proposed design requires only 16. The ones under the transverse girder are larger than those under the beams; but economically (considering erection costs) it is believed that costs are in the favor of the proposed design.

4. Prefabrication of the Cap (Transverse Girder)

In the original design, the cap of reinforced concrete had to be cast-in-place. In the proposed design, the steel section can be totally shop made and quickly field erected. The connection details between the beams and the girder involve only simple field bolting.

In summary of the proposed steel design, it is believed that all four of the desirable objectives have been met, without any cost penalty over the original design.

B — Concrete Bridge

1. Esthetics

Except for the end of the transverse girder, which is flush with the exterior face of the outside beam, the girder is invisible in elevation. The objective of recessing the "cap" to improve the visual lines is met in this redesign.

2. Deck Joints

The original bridge requires five transverse joints in the deck, while the proposed design requires only two (one at each end of the bridge). The deck at the center pier is considered fixed, so that a movement of approximately 1 inch is the maximum that would be expected at each end.

3. Bearings

Only 19 bearings are required in the proposed design, as opposed to 56 for the original structure.

4. Prefabrication of the Transverse Girder

Whereas the original bridge pier cap is cast-in-place concrete, the proposed design can be precast-prestressed concrete. The weight of this member is only 19 tons. Unfortunately, in order to keep the girder size small, the concrete has to have an ultimate strength of 6,800 psi. This is technically possible, but it will increase the cost of fabricating the member.

An additional expense would be incurred in fabricating the special steel hangers necessary to connect the beams to the girders. A similar type of steel hanger has been successfully used on several precast concrete bridges in Canada,[4] so that the strength and reliability of this special hanger are not a problem. Disregarding cost, the advantage of using the hanger shown is that it eliminates the need for notching either the beam or the girder and allows for an easily bolted field connection. Corrosion resistance is ensured by using "weathering" steel.

In summary of the proposed concrete design, it is believed that all four objectives have been met. However, there would be a cost penalty attached to the redesign as compared to the existing design. It is therefore recommended that the system proposed for concrete bridges be used only on those bridges where improved esthetic appearance is worth the extra cost involved.

ACKNOWLEDGEMENTS

Special appreciation is extended to Thomas J. Ogburn III, associate state bridge engineer of the Virginia Department of Highways, for his helpful assistance in furnishing material relating to the bridges used in this study; and to Wayne Tucker, student assistant at the Research Council, for his help in preparing the drawings.

REFERENCES

1. Virginia Dept. of Highways, Manual of the Bridge Division, Sections 1.7.51 & 1.12.2 on Bearings, 1969.

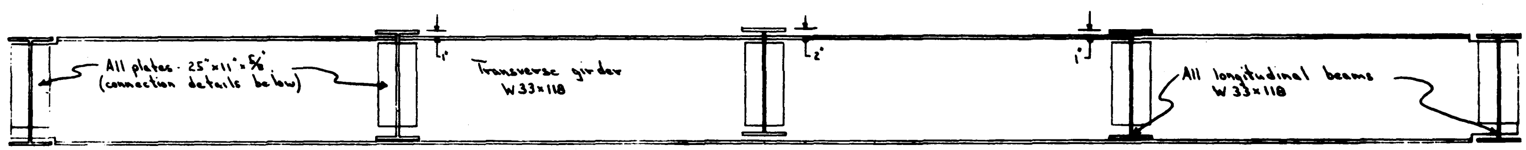
2. Specifications for Highway Bridges, AASHO, 11th ed., 1973.

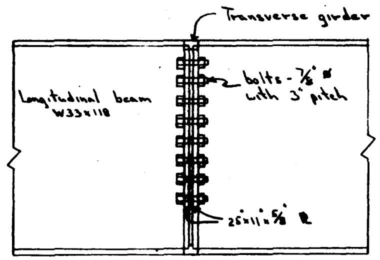
3. Structural Bearings by Fabreeka, Fabreeka Products Co., Inc., 1190 Adams St., Boston, Mass., 02124, 1970.

4. Behavior of the Cazaly Hanger Subject to Vertical Loading, J. S. Ife, S. M. Vzumeri, and M. W. Huggins, Journal of the Prestressed Concrete Inst., No. 6, pp. 48-66, Dec. 1968.

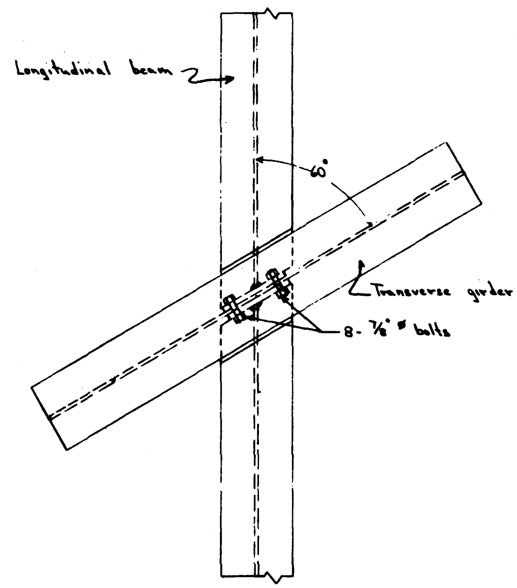
TRANSVERSE GIRDER

Scale ½" = 1'-0"

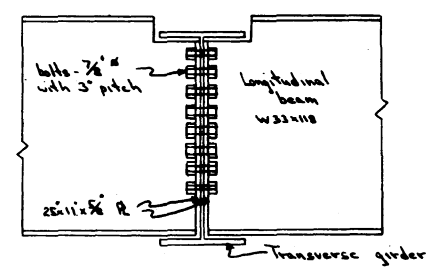




Exterior Connection
Scale 1" = 1'-0"



Beam Orientation
Scale 1" = 1'-0"



Interior Connection
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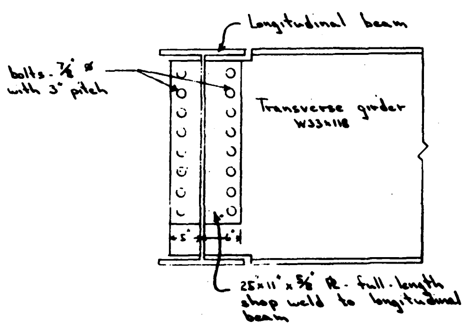
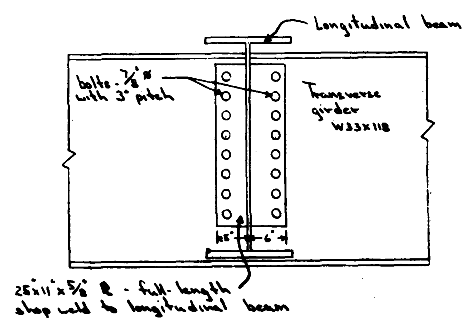
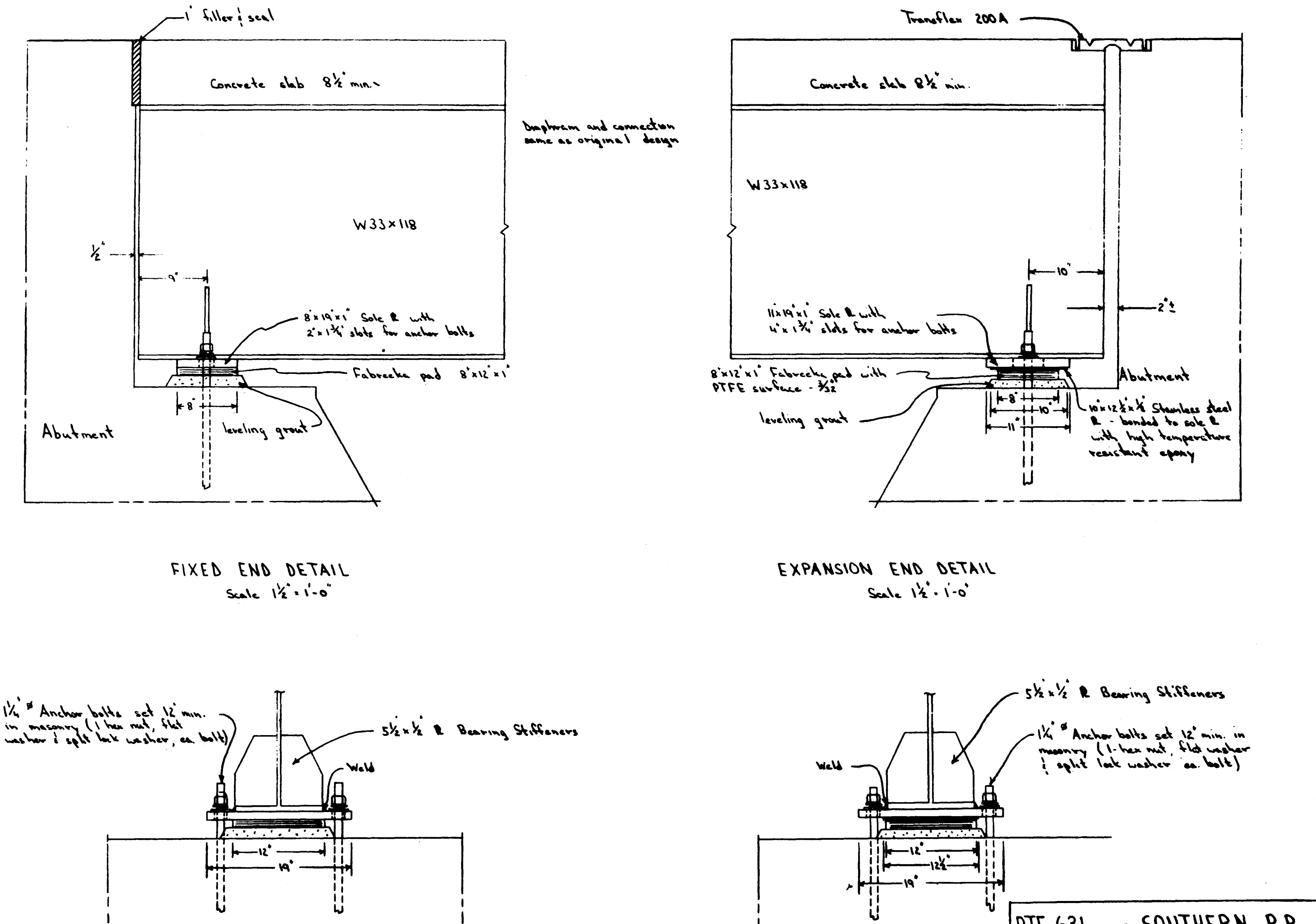




RT. 631 over SOUTHERN R.R.
Transverse Girder Detail
Sheet # 1

0630

UL0631



FIXED END DETAIL
Scale 1½" = 1'-0"

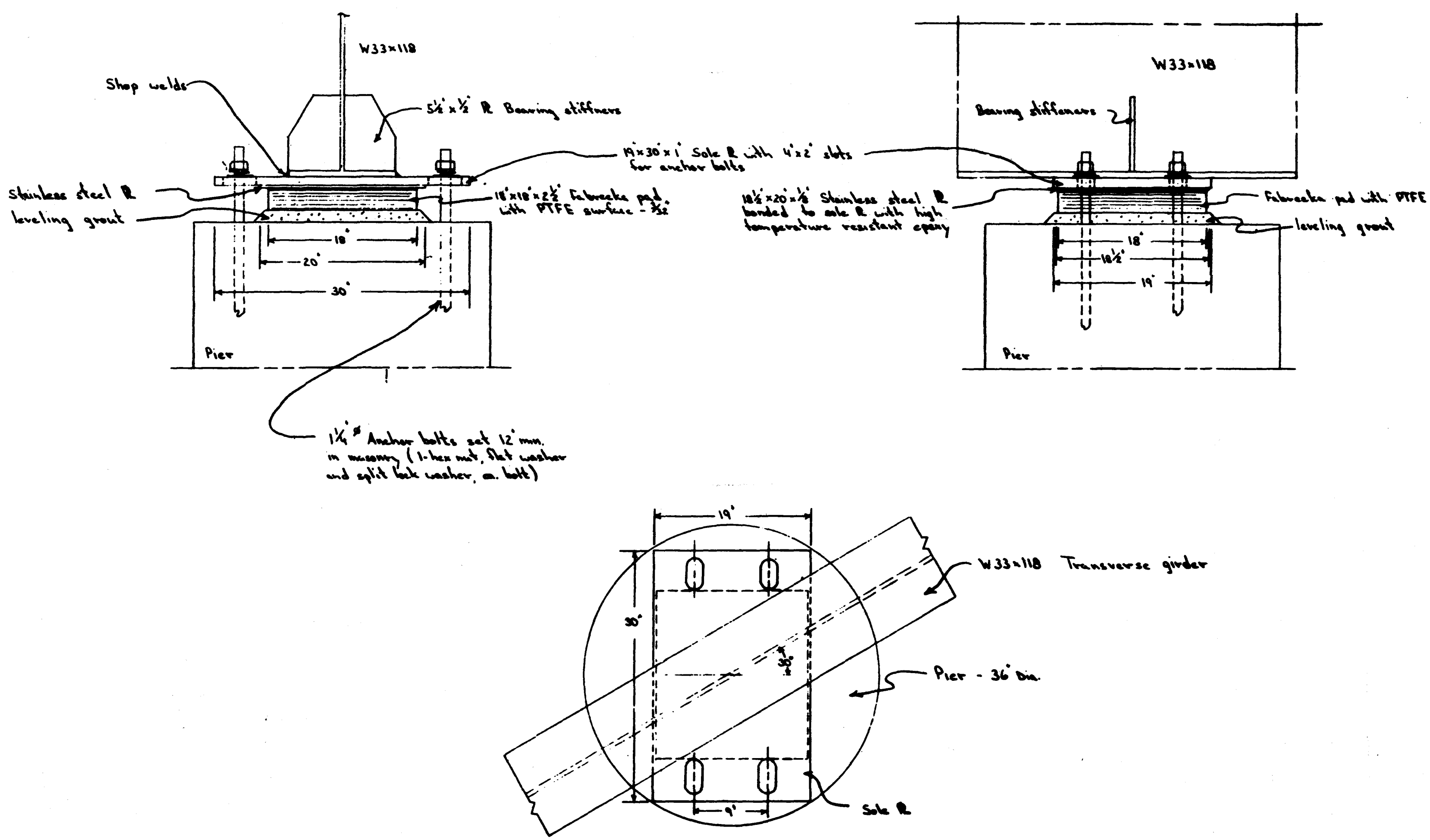
EXPANSION END DETAIL
Scale 1½" = 1'-0"

RTE. 631 over SOUTHERN R.R.

Bearings for Longitudinal Beams
Sheet #2

FLOATING CAP DETAIL

Scale 1½" = 1'-0"



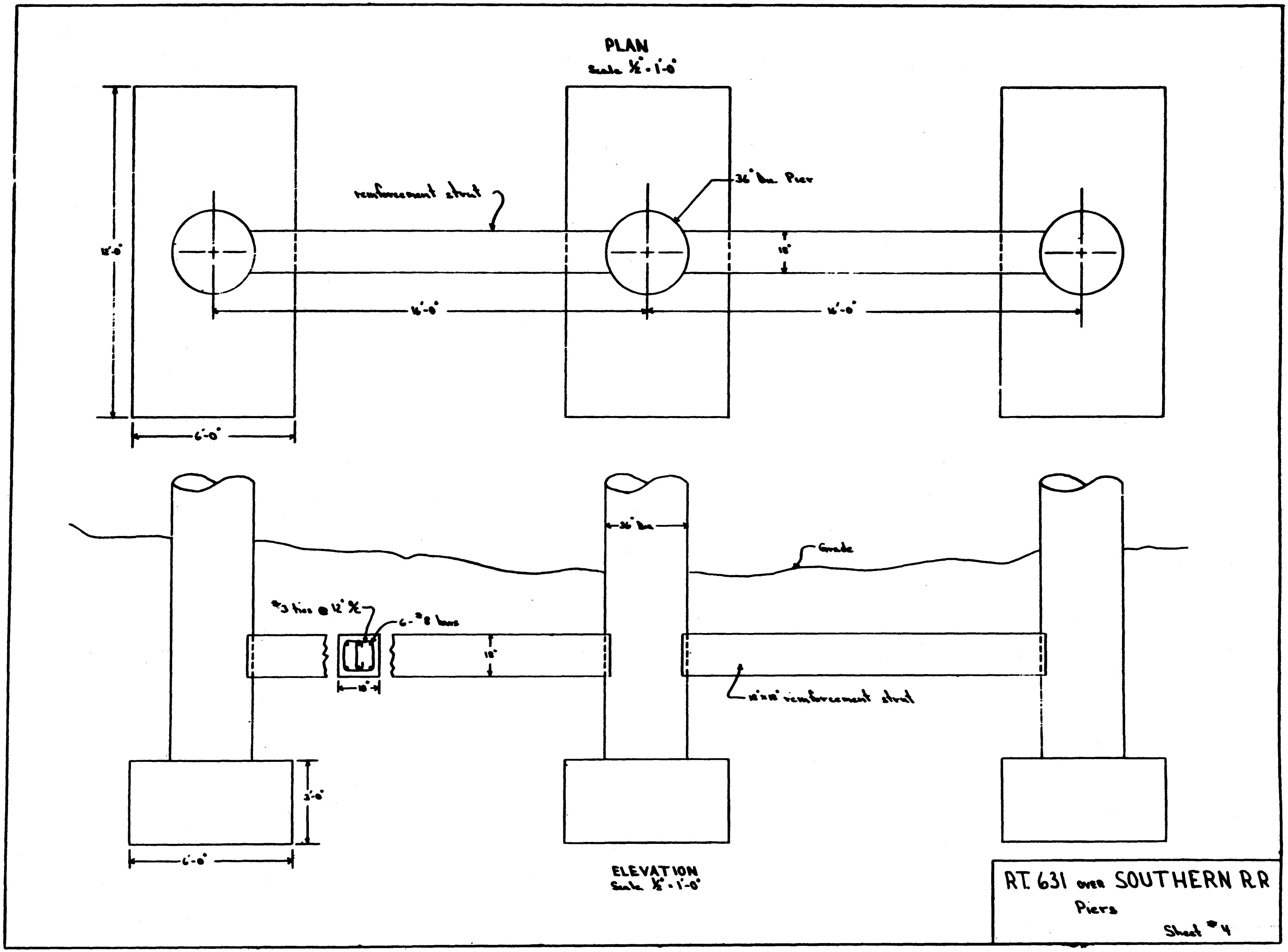
RT. 631 over SOUTHERN R.R.

Bearings for Transverse Girder

Sheet # 2

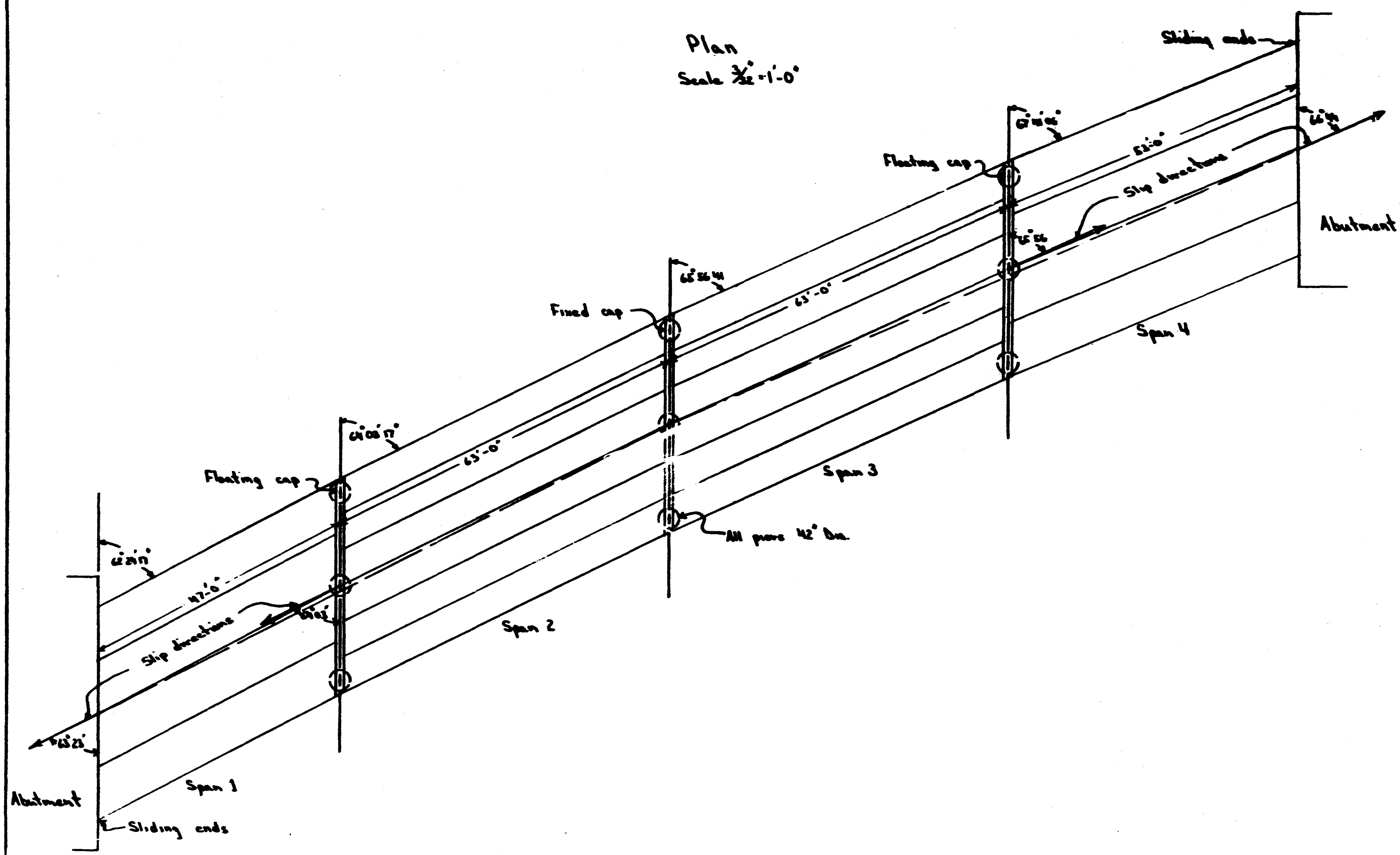
01 0632

0633


PLAN
Scale ½" = 1'-0"
reinforcement strut
36" Dia. Pier
16'-0"
16'-0"
6'-0"
Grade
36" Dia
#3 ties @ 12" ½
6-#8 bars
reinforcement strut
3'-0"
6'-0"
ELEVATION
Scale ½" = 1'-0"
RT. 631 over SOUTHERN RR
Piers
Sheet #4

Plan

Scale 3/32" = 1'-0"

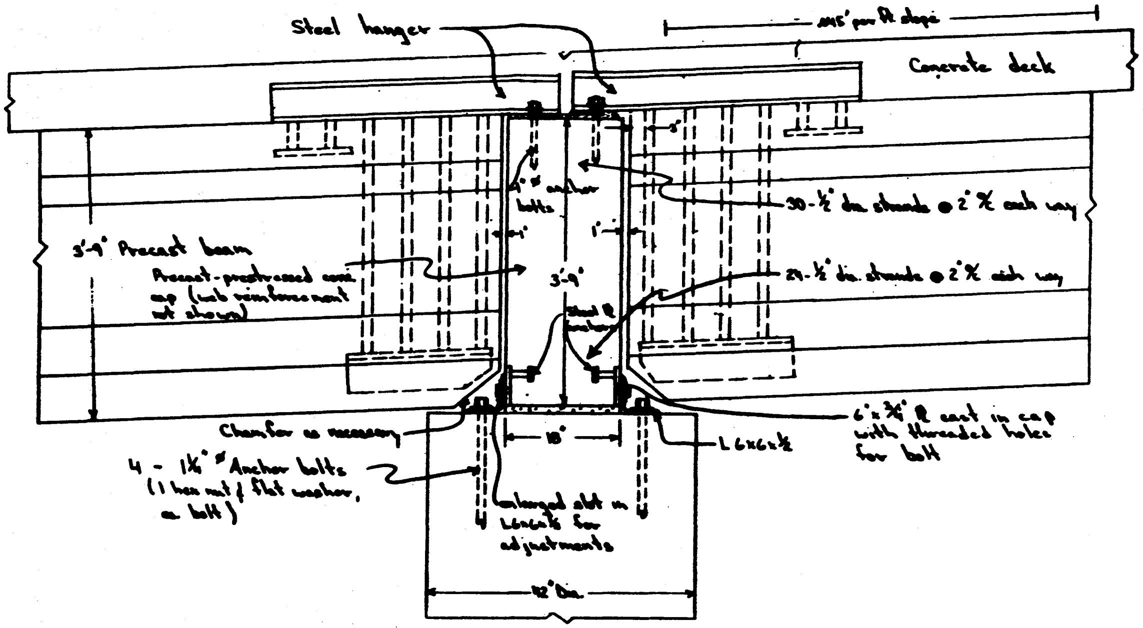


RT 19 OVER N&W R.R. AND RAMP A

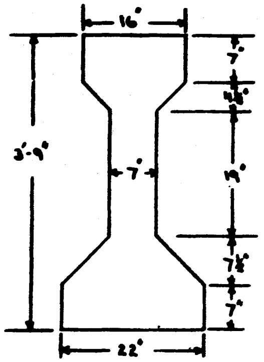
Plan

Sheet #5

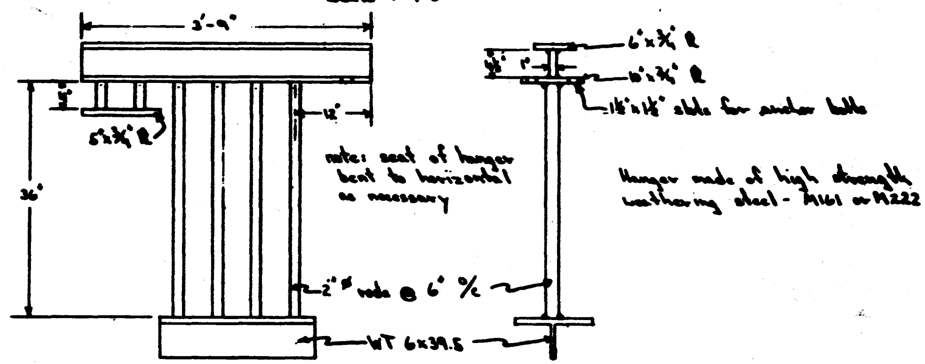
FIXED CAP DETAIL
Scale 1" = 1'-0"



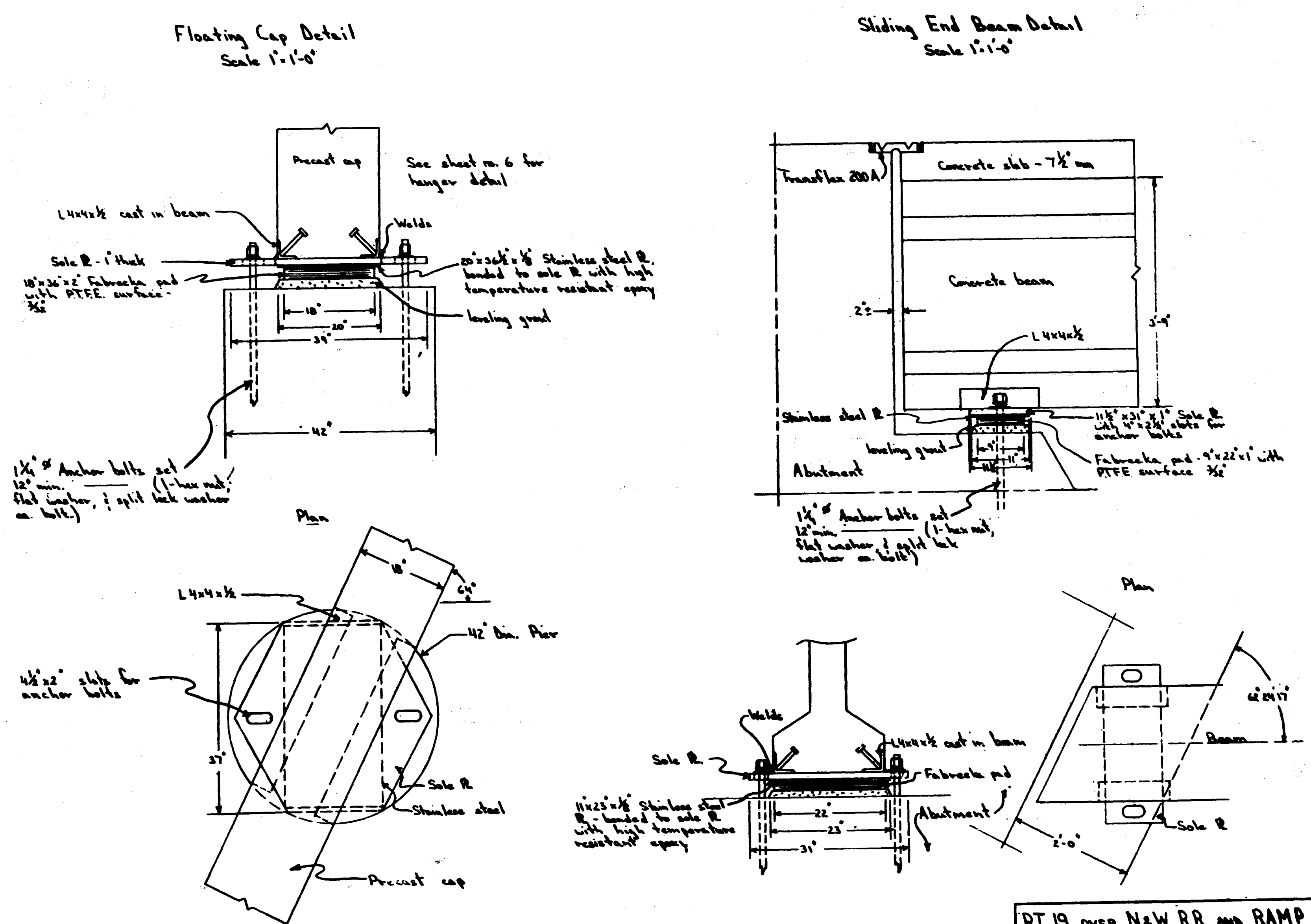
Beam Detail
Scale 1" = 1'-0"
(same as original design)



Hanger Detail (general)
Scale 1" = 1'-0"



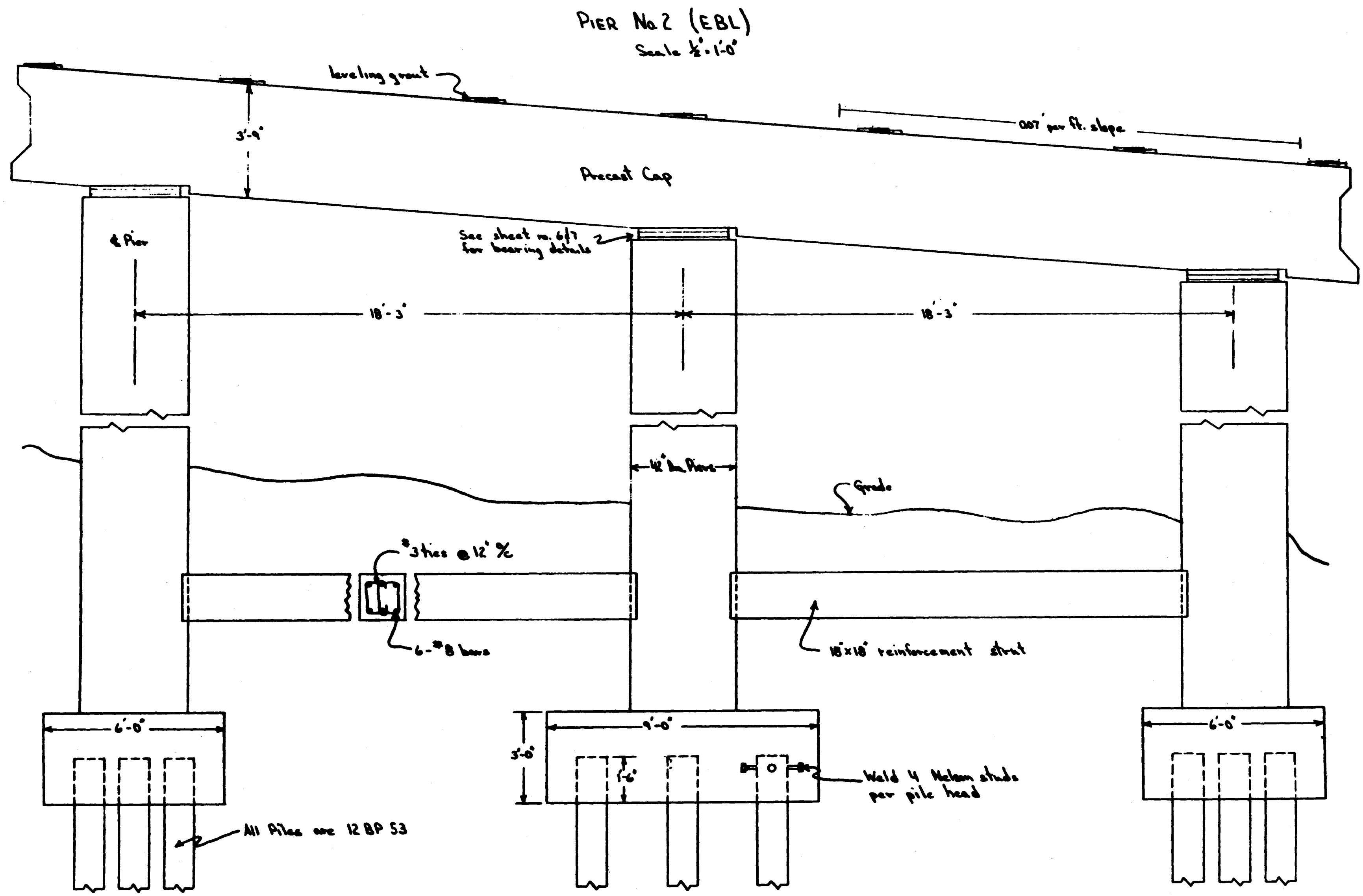
RT. 19 over N&W R.R. and RAMP A
Fixed Cap & Hanger Detail
Sheet # 6



RT. 19 over N&W RR and RAMP A

Bearings

Sheet #7



RT. 19 over N&W R.R. and RAMP A
Pier Detail

Sheet #8

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