REPORT 1967 - 01

VERMONT DEPARTMENT OF HIGHWAYS

Materials Division
Research Report

TESTING PROGRAM FOR BRIDGE RAILING ANCHOR

Report 1967 – 01

February 17, 1965

TESTING PROGRAM FOR BRIDGE RAILING ANCHOR BOLTS

Report R67-1

December 1967

VERMONT DEPARTMENT OF HIGHWAYS

John T. Gray, Commissioner

R. H. Arnold, Chief Engineer

A. W. Lane, Materials Engineer

Report Prepared By

Structural Concrete Sub Division

MARCH 20, 1968

A REPORT ON "BRIDGE RAILING ANCHOR BOLTS"

BY ARCHIE B. MCQUESTEN

DURING THE PAST FEW MONTHS A STUDY OF DIFFERENT METHODS AND MATERIALS FOR USE IN GROUTING IN BRIDGE RAILING ANCHOR BOLTS WAS UNDERTAKEN.

OUR FIRST ATTEMPT WAS THE USE OF DISCARDED SECTIONS OF CONCRETE TEST BEAMS. WE DRILLED 2" HOLES ABOUT 4" DEEP AND SET IN ANCHOR BOLTS WITH SEVERAL DIFFERENT GROUTS. THE ONES WHICH WERE STRONG ENOUGH TO BE CONSIDERED FOR USE WERE STRONGER THAN THE SMALL SECTIONS OF CONCRETE USED SO CONSEQUENTLY THE STRESS BROKE THE CONCRETE.

THE MATERIALS USED ON THE FIRST PHASE AND THEIR RESULTS ARE AS FOLLOWS.

3/4" BOLT - 4" IMBEDMENT

1. RAMCHEM EPOXY FORMULATION #223 - SPECIMEN FAILED AT 11,300 LBS.
2. RAMCHEM EPOXY FORMULATION WITH STONE - SPECIMEN FAILED AT 12,200 LBS.
3. HOT POURED LEAD - SPECIMEN FAILED AT 3,000 LBS.
4. EXPANSIVE CEMENT GROUT (PROPERLY CURED) - SPECIMEN FAILED AT 6,550 LBS.
5. EXPANSIVE CEMENT GROUT (DRIED OUT) - STARTED TO PULL AT 3,000 LBS. FAILED AT 5,600 LBS.
6. NORMAL CEMENT GROUT (PROPERLY CURED) - SPECIMEN FAILED AT 7,000 LBS.
7. NORMAL CEMENT GROUT (DRIED OUT) - SPECIMEN FAILED AT 4,950 LBS.

IT SHOULD BE NOTED HERE THAT THE RESULTS OF THESE TESTS ARE INCONCLUSIVE DUE TO THE SMALL SECTIONS OF CONCRETE IN THE SPECIMENS.

AT THIS POINT IT WAS DECIDED THAT A LARGER CONCRETE BLOCK WAS NECESSARY IN ORDER TO DEVELOP A HIGHER STRESS BEFORE BREAKING. A FEW 12" X 12" x 10" REINFORCED BLOCK WERE MADE AND CURED FOR A MONTH. THESE HAD DRILLED HOLES 2" X 6" IN THE CENTER OF EACH BLOCK: ANCHOR BOLTS WERE SET IN SEVERAL DIFFERENT GROUTING MATERIALS WITH THE FOLLOWING RESULTS.

8. STAR FASTENER (METAL 7/8" X 6" IMBEDMENT) - FAILED AT 5,600 LBS.
9. CEMENT MORTAR (SOME CURING) - FAILED AT 27,400 LBS.

10. SULFASET (RAPID CURING) - FAILED AT 12,800 LBS.

* 11. EMBECO (MASTER BUILDER) - FAILED AT 24,700 LBS.

* 12. HORN THIOPOXY 60 - FAILED AT 14,950 LBS.

* 13. RAMCHEM (EPOXY FORMULA 223) - FAILED AT 32,250 LBS.

HERE IT IS IMPORTANT TO NOTE THAT * MATERIALS DEVELOPED MORE STRENGTH THAN THE CONCRETE TEST BLOCK COULD STAND, THEREFORE, THESE STRENGTH RESULTS ARE THE MAXIMUM THAT THE CONCRETE WOULD STAND AND NOT NECESSARILY THE MAXIMUM STRENGTH OF THE MATERIAL.

IT IS ALSO IMPORT NT TO NOTE THAT ON EVERY SAMPLE OF THE NONSHRINKING GROUTS THERE WERE SOME CRACKS DEVELOPED AT THE SURFACE EDGES; THESE WOULD DEFINITELY HAVE TO BE SEALED WITH SOME OTHER MATERIAL TO KEEP OUT SALT BRINES.

IT IS ALSO IMPORTANT TO NOTE THAT THE SELF-EXPANDING GROUTS SHOULD NOT BE USED ADJACENT TO ALUMINUM MATERIALS AS ELECTROLYTIC ACTION WILL QUICKLY CORRODE THE ALUMINUM.

COST CONSIDERATION:

THE COST FOR MATERIAL OF HORN THIOPOXY 60 AND THE RAM CHEM EPOXY COMPOUNDS ARE APPROXIMATELY $1.00 PER BOLT WHEREAS THE CEMENT AND NONSHRINKING GROUTS ARE MUCH LESS BUT NOT WORTH THE DIFFERENCE IN PRICE IN COMPARISON TO A NORMAL CEMENT MORTAR GROUT. (HOWEVER, WE FEEL THAT THE "THIOPOXY 60" COMPOUND WAS QUITE PUNKY IN APPEARANCE COMPARATIVELY.)

LABORATORY RECOMMENDATIONS: ORDER OF PREFERENCE.

1. USE OF A LONGER ANCHOR BOLT TO EXTEND THROUGH THE ENTIRE DEPTH OF CONCRETE WITH NUTS AND WASHERS.
2. THE USE OF AN APPROVED EPOXY COMPOUND (STRAIGHT EPOXY).
3. NORMAL CEMENT MORTAR GROUT PROPERLY CURED AND WATERPROOFED.

R.B.M. Lucatero

HIGHWAY DEPARTMENT OFFICE MEMORANDUM

TO: R. I. Rowell, Materials Engineer

FROM: E. F. Perkins, Chief Bridge Designer

DATE: January 2, 1968

SUBJECT: Testing Program for Bridge Railing Anchor Bolts

Following the preliminary tests of grouted anchor bolts on December 22, 1967 it was felt that additional testing and evaluation were necessary before making a final decision on the grout system to be used when making new railing installations on existing bridges. The attached testing program was developed to aid in making this decision.

We have determined that the Planning Division has research funds available for this sort of program and in order to receive approval for the use of these monies it is necessary to have an estimate of the costs involved. Accordingly, would you review this program outline and give us your estimate of material and labor cost involved to carry out each of the phases noted.

We believe the material to be self-explanatory, but if you have questions regarding any of the details please contact either myself or R. L. Merchant.

EFP:RLM:pmp
Attach.

Derby I 91-3 (1) PE
Derby I 91-3 (22) Const.
December 29, 1967

TESTING PROGRAM FOR BRIDGE RAILING ANCHOR BOLTS

Purpose and Scope:

This program is designed to determine the materials and methods to be used when installing bridge railing, which conform to 1965 AASHO design specifications, on the existing safety walks on the I 91 (NB) over U.S. 5 bridge. The program is designed to study the resistance of an individual anchor bolt subjected to tensile force only and to confirm the design of the standard bolt group.

Objectives:

1. Determine effectiveness of various materials used to grout bolts into holes drilled in precast blocks.

2. Determine depth of embedment required to develop anchor bolt tension in existing bridge safety walks.

Specifications:

A. Materials:

1. Test Blocks. Two types of test blocks are to be prepared as indicated on the attached sheets. Test block "A" is a heavily reinforced block designed to determine the effectiveness of several materials as a grouting system. Test block "B" is intended to simulate the actual conditions of concrete depth and reinforcing steel distribution to be found in existing safety walks. Blocks are to be of Class AA Concrete, properly cured and reinforced with Intermediate Grade Reinforcing Bars. Holes are to be drilled after curing to depth necessary to provide embedment indicated.

2. Grout Systems. Several systems of commonly available material are to be tested, including:

- a. Portland Cement grout
- b. Non-shrink cement grout (commercial grade)
- c. Epoxy-sand grout
  - 1. Ram-Chem
  - 2. other as available
- d. Epoxy (without aggregate)
  - 1. Ram-Chem
  - 2. other as available
- e. Sulphide Materials
  - 1. Sulfex
  - 2. Porock
  - 3. Leadite

Grout systems are to be evaluated using test block "A". The minimum acceptable ultimate strength of the system shall be 40,000 pounds. The systems shall be observed for rapid deterioration under service conditions (freeze-thaw and salt action) or action which would lead to maintenance problems. Systems to be designed according to usual practice or manufacturer's recommendations.

B. Procedure:

Phase I. Evaluation of the various grout systems using Test Block "A", to determine the specific system to be used. An alternate system may be designated. Two (2) test blocks are to be prepared for each grout system.

Phase II. Evaluation of the effectiveness of various depths of embedment using the grout system selected in Phase I and Test Block "B". Two (2) test blocks are to be prepared for each of the following embedment depths: 4", 6", 8", 10". Test loading is to be carried to failure. Minimum acceptable ultimate strength is to be 40,000 pounds.

Phase III. Full scale test of SB-R1-64 rail post bolt group using grouted anchor bolts and subjected to 1965 AASHO rail post loading. Anchor bolts to be set with embedment and grout system selected in Phases I and II.

C. General:

Testing is to be carried out by the Materials Division, Vermont Highway Department. Detail test procedures, records and reports are to be developed by the Materials Engineer.

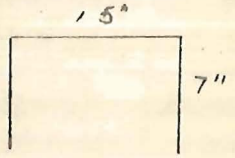
BY ..... DATE .....
CHKD. BY ..... DATE .....

SUBJECT TEST BLOCK "A"
To test ability of epoxy to develop 9a²

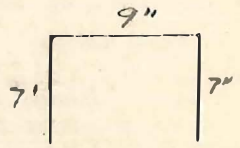
SHEET NO. ..... OF .....
JOB NO. I 91-3(1)
Derby

ALL BARS #4

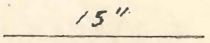
4-"A"s



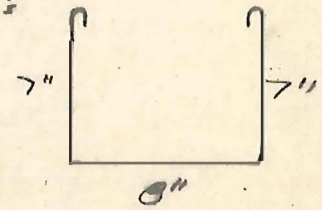
4-"B"s

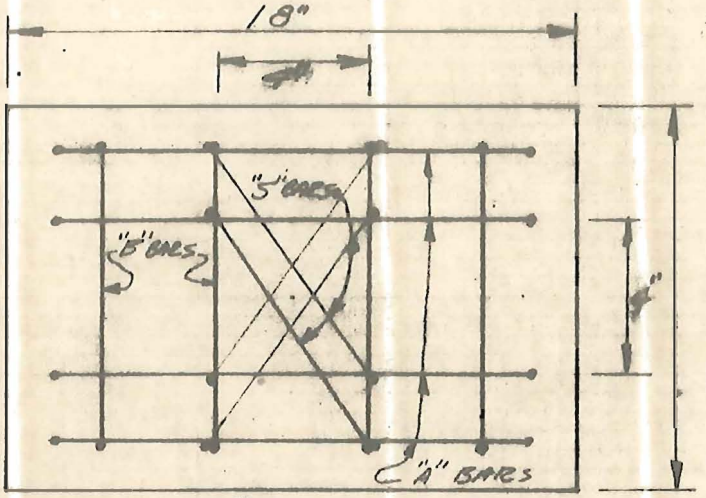


2-"C"s

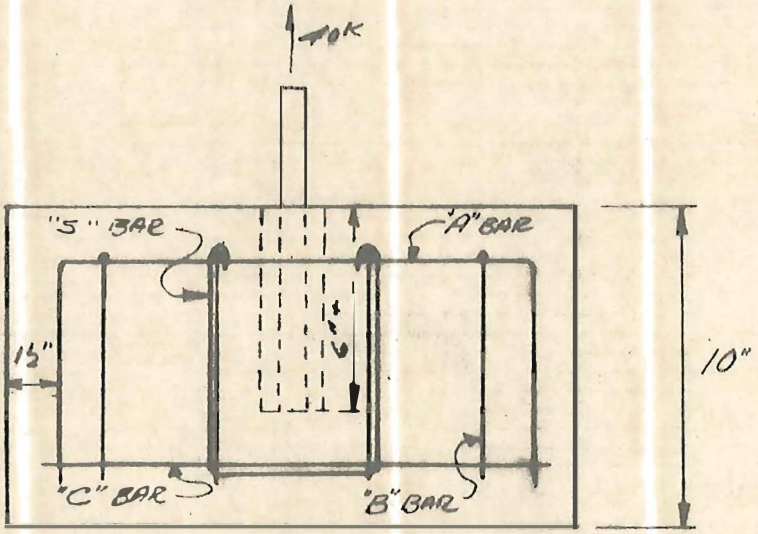


4-"S"s





PLAN



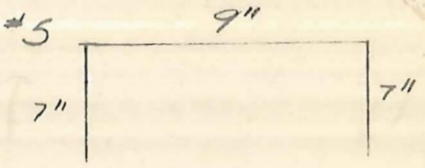
ELEVATION

BY ..... DATE ..... SUBJECT Test Block "B" SHEET NO. ..... OF .....

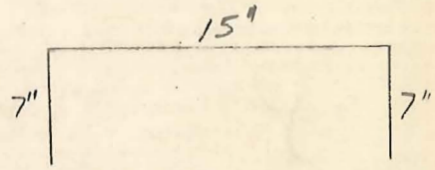
CHKD. BY ..... DATE ..... To Find Required JOB NO. I91-3(1)

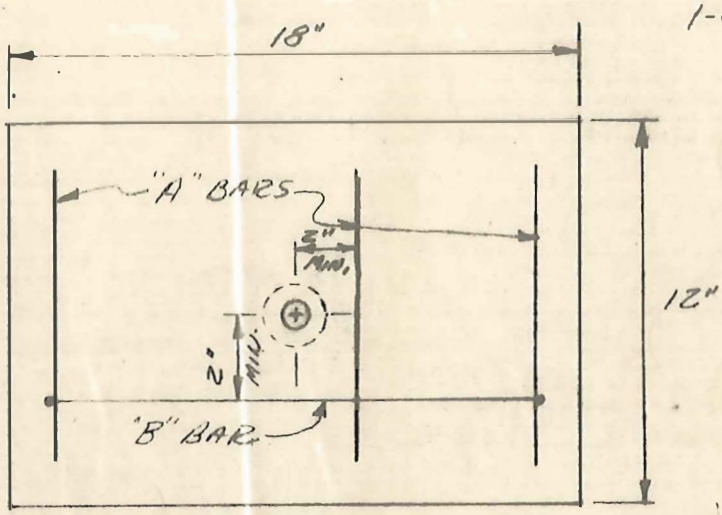
Anchor Bolt Depth Derby

3-"A"-#5

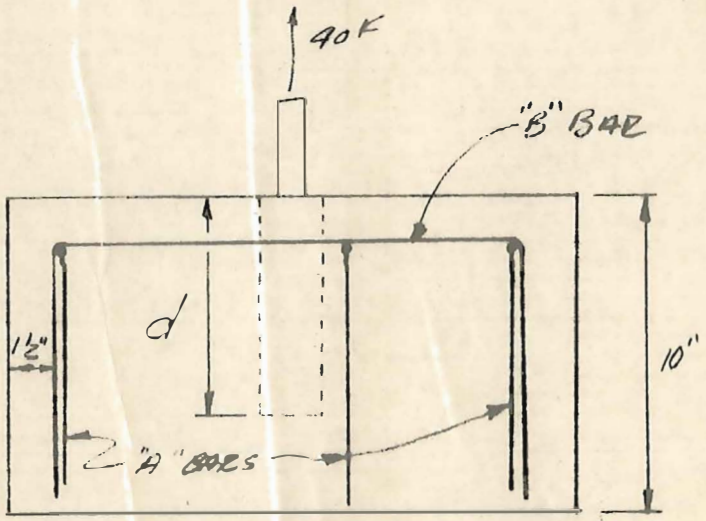


1-"B"-#4





PLAN



ELEVATION

d = bolt embedment

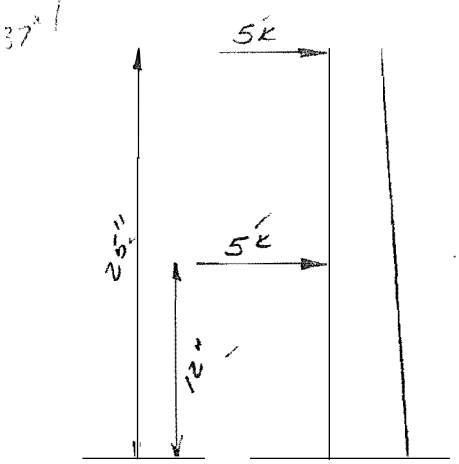
BY K.L.J. DATE 12/13/67 SUBJECT INVESTIGATE RAILING ANCHOR BOLTS - EXISTING (WB) BRIDGE WITH 1965 AASHO LOADING SHEET NO. 1 OF 2

CHKD. BY R.W.M. DATE 12-14-67 JOB NO. I91-3(1) Derby

Robert merchant

NEGLECT WIND LOAD ?

50# x 8' = 1.4^K



TRANSVERSE LOAD

M@ BASE 37(.04) : 15

25(5) = 125' IN-K

12(5) = 60' "

185 IN-K

2 ea

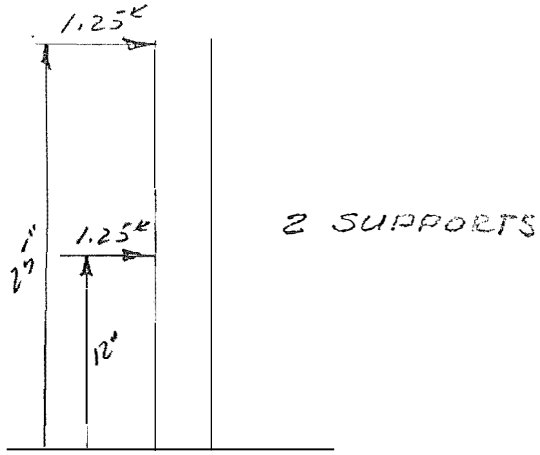
ASSUME FULL LOAD IS TAKEN BY FRONT ROW OF BOLTS AND PLATE WILL PIVOT ABOUT BACK OF PLATE

MOMENT ARM = 5'2 + 1'8 = 6'5/8"

= 6.625"

FORCE IN EACH FRONT BOLT

$\frac{185 \text{ IN-K}}{6.625"}(.5) = 13.96$ (15.1)



2 SUPPORTS

LONGITUDINAL LOAD

M@ BASE

25 (1.25) = 31.25' IN-K

12 (1.25) = 15.0' IN-K

46.25' IN-K

ASSUME PIVOT ABOUT EDGE OF FLANGE ✓

MOMENT ARM = $3\frac{5}{8} + 1\frac{1}{2} = 5\frac{1}{8}$"

= 5.125.

FORCE IN 1 FRONT AND 1 REAR BOLT

$\frac{46.25}{5.125}(.5) = 4.51$

MAX. FORCE IN ONE FRONT BOLT = 18.47K (19.61)

ASTM - A307 - 65

7/8" BOLT TENSILE STR. = 25.9K MIN. (55,000 PSI)

OK - for yield strength

.462 x 13.5 = 6.2^K No Good for Working Strength Design

TRANSVERSE LOAD

ASSUME PIVOT ABOUT BACK ROW OF BOLTS

MOMENT ARM = 5.5"

FORCE IN 1 FRONT BOLT

$\frac{195}{5.5}(.5) = 16.82^K$

LONGITUDINAL LOAD

ASSUME 1 FRONT BOLT TAKES TOTAL FORCE ABOUT POINT AS ABOVE

FORCE IN FRONT BOLT

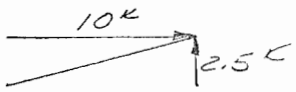
$\frac{96.25}{5.125} = 9.02^K$

TOTAL FORCE FROM $M = 25.84^K$

ALLOW = 25.9^K (MIN) 8.12^K

(55,000 PSI) (13,500 PSI)

SHEAR



$10^2 + 2.5^2 = R^2 = 106.25$

$R = 10.31$

SHEAR PER BOLT = $\frac{10.31}{4} = 2.58^K$ $f_v = \frac{2.58}{.462} = 5.58$

P. 5-22 AISC SPEC'S

FOR A307 BOLTS $F_v = 20,000 - 1.6 f_v \leq 14,000$

CHANGE TO $F_T = 55,000 - 1.6 f_v$

$F_T = 55.0^{ksi} - (1.6 \times 5.58) = 46.1^{ksi}$

TENSILE STRENGTH OF BOLT = 46.1 (.462) = 21.3 kips

USING STANDARD BASE ✓

(TRANS.) PIVOT ABOUT BACK ROW OF BOLTS ✓

MOMENT ARM = 8.25" ✓

FORCE IN 1 FRONT BOLT

$\frac{195}{8.25}\left(\frac{1}{3}\right) = 7.47^K$

LONGITUDINAL

SAME AS ABOVE

ASSUME FORCE IN CENTER BOLT = 1/2 FORCE IN OUTSIDE BOLT ✓

$96.25 = P(3.4375) + 2P(6.875)$

$P = 2.67$,

$2P = 5.38^K$

TOTAL MAX FORCES = 13.05^K

¾" BOLT FROM STANDARD BOLT AS ABOVE

$\frac{12.05}{.4418} = 29,086$ PSI

$\frac{12.05}{.462} = 27,814$ PSI

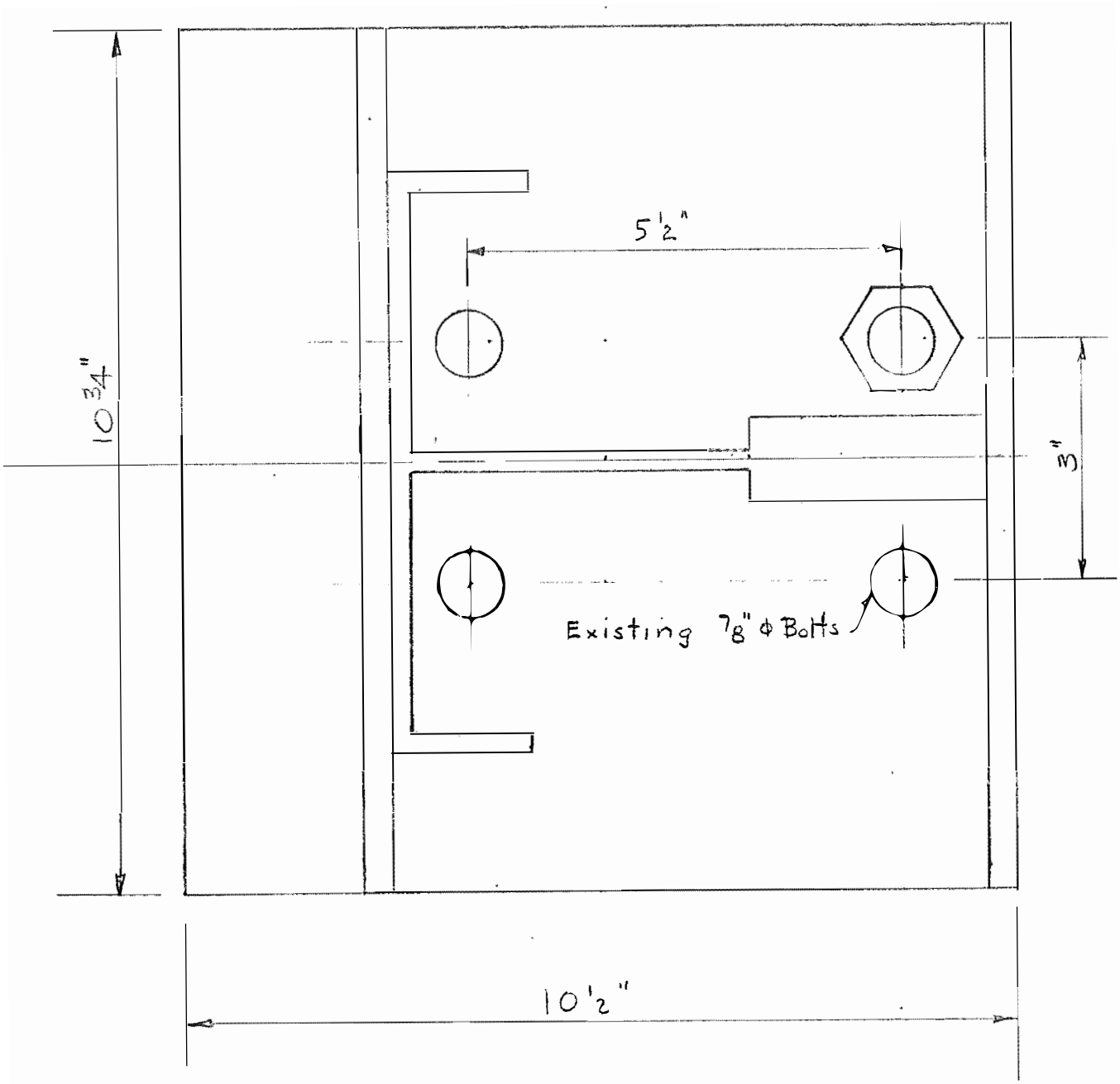
1 7/8" root area

BY A.J.C. DATE 11/10/67 SUBJECT Derby U.S.S N.B Post Base SHEET NO. ..... OF .....

CHKD. BY ..... DATE ..... JOB NO. .....

1/2" = 1"

665 Base Extrusion



S_T = 48,700 psi ALLOW. = 13,500 psi

S_S = 5,680 psi ALLOW = 11,000 psi

#877

HIGHWAY DEPARTMENT

OFFICE MEMORANDUM

TO: E. F. Perkins, Chief Bridge Designer

FROM: R. L. Merchant - Bridge Division

DATE: December 15, 1967

SUBJECT: Railing Anchor Bolts

We have investigated the anchor bolt stresses for 1965 AASHO loading conditions using both the SB-5G and the SB-R1 base plates.

Using the SB-5G bolt layout (4 bolts) the maximum load per bolt is 27.2 kips. The allowable load on a 7/8" A307 bolt is 6.2 kips using working stresses and 25.4 kips when using minimum yield strength criteria. Therefore, it does not appear feasible to use the present anchor bolts when changing to the 1965 loading conditions.

Using the SB-R1 bolt layout (5 bolts) the maximum load per bolt is 13.5 kips. The stress in a 3/4" upset end bolt is 30.5 ksi and in a 7/8" bolt (root of thread) it is 29.2 ksi.

Recommend that either 7/8" galvanized A325 HS bolts or stainless steel HS bolts be installed as the three (3) front bolts (under face of rail) when converting existing rail installations to SB-R1 railing.

RLM:pmp
cc: Archie McQuesten (w/a)

File

Archie McQuesten

HIGHWAY DEPARTMENT — OFFICE MEMORANDUM

TO: R. H. Arnold, Chief Engineer VIA: E. H. Stickney

FROM: L. M. Bjorn, Bridge Engineer LMBjorn

DATE: April 8, 1968

SUBJECT: Bridge Railing Anchor Bolts

Background information on a report by A. B. McQuesten dated March 20, 1968 titled "A Report on Bridge Rail ing Anchor Bolts", is as follows:

Plans for the Derby I 91-1 (22) project provided for removal of the cast aluminum railing posts and the installation of our present standard continuous rail with extruded posts. Present AASHO railing loads would cause overstress in the existing anchor bolts. The old post had four (4) bolts, while our present post has five (5) bolts in a larger group.

To install the new bolts in the existing concrete required a new concept, which we felt would be best provided by a bolt grouted into a drilled hole. A satisfactory grouting system was not readily apparent, so we asked the Laboratory for their recommendations.

After the tests using discarded test beams showed poor results, we developed an extensive program using larger reinforced blocks. The cost of this program was estimated to be $ 3,000 and no funds were found to be available to support this. As Mr. McQuesten notes a few blocks were made, but these apparently were not adequately reinforced and failed early giving inconclusive results.

The selection of a satisfactory grouting system cannot be made from our tests to date. It is our feeling that such should be determined for use in reconstruction projects and by maintenance personnel.

We recommend that a testing program be funded which would yield more conclusive results and the Laboratory authorized to carry out the program. If they feel the program to be beyond their capability, an arrangement should be made with one of the Universities.

LMB:RLM:pm
cc: A. B. McQuesten