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PREFORMED ELASTOMERIC BRIDGE JOINT SEALERS
INTERIM GUIDE FOR DESIGN AND CONSTRUCTION OF JOINTS

by

George S. Kozlov

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The paper suggests armored joint construction sealed with preformed elastomeric sealers as the most advantageous solution to the problem of sealing joints in bridges.

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NEW JERSEY DEPARTMENT OF TRANSPORTATION
DIVISION OF RESEARCH AND DEVELOPMENT

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As a result of several years of research which culminated in the construction of two experimental bridges, it now becomes possible to present engineers with procedures for the design and construction of adequately sealed bridge joints. These procedures are offered as an interim solution until research provides further evidence and/or improvements.

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INTRODUCTION

Since 1965 the New Jersey Department of Transportation has been conducting a research study dealing with Preformed Sealers for Bridge Decks. The accomplishments of this study were presented in three previous papers (1,2,3). In the first of these articles it was stated that there continues to be a lack of an adequate solution to this problem of effectively sealing joints in bridges. In this and the subsequent papers a succession of solutions was offered covering the design of bridge joints and preformed sealers, their application in construction, and the thermal characteristics of bridge end movements. In 1969, an experiment was undertaken in which two bridge structures were built utilizing these suggested design and construction procedures; all joints were redesigned and constructed as recommended by the research. Armored and sawed joint construction was used for expansion and fixed joints respectively. The purpose of this paper is to present engineers with procedures for design and construction of adequately sealed joints, based on the findings of New Jersey's previous subject research and the results of this experiment.

SUMMARY OF THE SUPPORTING RESEARCH

For a period of several years continuous field observations were gathered on 17 bridge structures scattered throughout the State of New Jersey. Based on the trends revealed by these observations an analysis was made of present and proposed joint construction and sealing methods and practices, including those of other states and countries. The findings indicated that present sealing systems are malfunctioning primarily due to inadequate construction practices. Nevertheless it appeared that one particular system, preformed elastomeric sealers, could be made to function properly, provided the sealer material and bridge behavior were understood; new design and construction methods were offered(1).

Supported by up-to-date knowledge of sealer material, tentative qualification and identification specifications were developed. These specifications, being realistic and closely related to field application, are now furnishing producers and users with practical ways to develop and/or identify a reasonably adequate product(2).

Since field observations led to the conclusions that the bridge deck end movements could, to a great degree, be identified as thermal in character, an attempt was made to summarize the reliable theoretical background of the thermal characteristics of a concrete bridge deck(3).

The information gained in the investigation of elastomeric sealers and joint movements eventually led to the development of new procedures for bridge joint design and construction. Finally two experimental bridges were constructed to test these new procedures.

To assure the correlation between the sealer specification and its functional application on one hand, and the temperature and bridge end movements on the other, an ongoing research program has been initiated.

TEST INSTALLATION

The subject experiment was developed and executed utilizing as a basis the techniques outlined in the first two papers (1,2). The specific procedures used are summarized in Guides "A", "B", and "C". These sections describe, respectively, the selection of the sealer, construction procedures of an armored joint, and the design of the joint armor. The sawed joint procedure is omitted because it proved ineffectual. As part of the experiment the sealer material was evaluated in accordance with latest New Jersey Department of Transportation Preformed Sealer specifications(2).

As is frequently the case, there were deviations in design and especially in execution of construction from that recommended by Research mostly due to unforeseen circumstances. In New Jersey the actual design and the construction of joints and installation of sealers is accomplished through consultants and contractors. With guidance from the Department's research division the consultant designed the joint armament and supplied supplemental construction drawings. Unfortunately, these drawings specified among other details, much too excessive an anchor spacing (18 inches).

To remedy the anchorage it was supplemented by welding every available reinforcement bar to the joint's armor. Regrettably, some construction deviations also occurred, such as in the forming and sawing of joints, which could not be remedied. These problem areas are hereinafter mentioned in order to better understand the conclusions and recommendations that follow.

The two experimental bridges have now been open to traffic for two full years. In the spring of the first and second years Dye Tests were performed on these bridges for the purpose of detecting joint leakage.

DYE TESTS

Specifically, various colors of dye were used to locate the origin and determine the cause of leaks in bridge joint sealers. The dyes were poured at carefully selected points and were traced by observation of their destination. Generally the tests were performed during weather conditions that would be most conducive to joint leakage; i.e., freezing and thawing with precipitation. Observation continued until results were ascertained. The only leak which to date has occurred in a fixed joint is attributed to a fault in construction. Complete details, with schematic diagrams, are available on request.

CONCLUSIONS

To date, the sawed and armored joints on both bridges do not leak.

The results of this experiment appear to bear out the earlier suggestions made regarding proper design and construction procedures(1,2).

It is essential to recognize the realities of joint design and construction. IN THE ABSENCE OF ADEQUATE QUALITY CONTROL IN CONSTRUCTION NO MATERIAL AND NO METHOD OF ITS APPLICATION WILL SUCCEED. For this reason alone, perhaps the formed and sawed joint methods of construction must fail. In the opinion of the writer, the joint-sealing and construction should be placed into the hands of specialists, with adequate construction supervision. In addition this experiment leads to the following conclusions, that reflect the current state-of-the-art regarding joint design and construction practices and procedures.

1. The experimental design approach initiated on these bridges has proved its merit. Briefly, basic design principles are:

1.1 Deck joints shall be horizontally straight from outer edge to outer edge and the sidewalk joints shall be directly above it in the same straight fashion; main sealers are placed out to out.

1.2 Sidewalk sealers are placed also out to out, i.e., bottom of curb to outside, with only one vertical shallow bend (60°) at the curb. For details see Figures B2 through B5.

2. The sawed joints are functioning because they are "fixed joints" i.e., they do not incur the degree of movement of an "expansion joint". Also they have the advantage of being designed in accordance with the specialized procedures offered in Guide "A" of this paper. To remedy the results of poor sawed-joint construction the sealer in a few of the experimental joints should have been replaced. To this and any other similar efforts the following word of caution is offered.

Replacement of sealers is ill-advised unless it is performed with great care; it incurs considerable expense, and also inconveniences the riding public. For these reasons, upon the advise of the writer, no sealers were replaced in this experiment. If the sealers in fixed joints (sawed) were replaced, as they should have been in at least **one bridge**, care should be taken not to jeopardize the functional efficiency of the replacement sealers. Since the joints were sawed improperly, they would first need to be resawed, then thoroughly cleaned and/or adequately repaired and prepared. Immediately thereafter a proper size continuous sealer should be installed in accordance with the originally established procedures. Sufficiently prior to installation, sealers must be tested and approved by the Department's Bureau of Quality Control laboratory. Continuous and adequate supervision is most essential. Of course, the best way to replace sealers is to utilize armored type of joint construction with the hereinafter proposed procedures.

3. The armored type of joint design appears to be the most advantageous of existing solutions to the joint design problem.

RECOMMENDATIONS

The recommendations given below are based on the aforementioned conclusions.

1. Adoption of the bridge joint design approach as outlined in the New Jersey State Report #29 and later published in HRR #200

and #287 and once more summarized in Guide "A" is advised. In both experimental bridges, design and development of joints was fashioned in accordance with suggestions made in the report and papers.

2. Also suggested is the adoption of the design and construction procedures for joint armor as offered in Guides "B" and "C". For further illustration of armored joint design and development details, see References 4 and 6. The last reference has been clarified by Mr. L. G. Deuce, Assistant Chief Engineer, in behalf of the author Mr. Holland. The essence of this clarification is as follows:

    a. ".....soundly constructed joints designed in accordance with the instructions given in Clause 7e should be satisfactory....."

    b. ".....it was not intended to limit the application of the rules from applying to the turned down angle type of armoring."

    c. ".....the vertical loading is taken directly from BS 153 (7) and has not so far been substantiated by actual loading measurements on joints. The horizontal loading was recommended as a result of the Survey of Expansion joints."

In the U.S.A. there seems to be no specification available that is directly involved in the design of Armored Joints. For this reason, to fill at least an interim need, the writer has adopted and suggests the use of existing related AASHO specifications (8) as shown in Guide "C".

3. For bridges with spans larger than those indicated either in Table A1 or A2 in Guide "A" experimental installation of "modular sealing system" advocated by S.A. Watson (5) should be attempted. The design approach for the modular system is similar to the one suggested above.

4. Future Research - Dynamic Load Tests for Armored Bridge Joints: Although various types of armored joints are offered, their design is often questionable from structural as well as functional points of view.
   Considering the structural aspect of the design of an armored joints there are basically two problems which may lead to either structural failure or, on the other hand, gross over-design.
   The first problem is that of determining accurate load distribution factors and dynamic load and impact factors. The second problem is in the actual stress analysis of the structurally indeterminate armored joint. To this end future research is proposed. The author has several ideas regarding an appropriate approach to such investigations and could provide pertinent details upon request.

5. The sealer selection should be guided by the realization of the fact that there are TWO COMPLETELY DIFFERENT TYPES OF PREFORMED SEALERS.

One is a COMPRESSION sealer type identified by the capability of producing considerable pressure when compressed. The other sealer type could be called COMPRESSION-EXTENSION sealer and presently is identified as being very pliable, exerting little pressure when compressed, but capable of accommodating some elongation if properly installed.

The preformed compression sealer variety, which already has proven itself in widespread application, is the one herein discussed. The compression-extension sealer type should be researched separately since the prerequisites of its use are the positive means of its adhesion to the joint's sides. With the advent of prefabricated joint armament systems this type of sealer could become a reality.

SIGNIFICANCE OF FINDINGS AND CLOSING COMMENTS

This experimental construction includes only two bridges each having only one simple span, yet far reaching conclusions and broad recommendations have been made in this paper. This is possible because these experimental installations represent several years of research effort in this field. In the absence of any other similar data, the recommendations made here are offered as an interim solution until more scientific information becomes available.

ACKNOWLEDGEMENT

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GUIDE "A"

SELECTION PROCEDURE FOR SEALERS

The selection procedure described herein accomplishes, basically two purposes. It establishes the size of sealer to be used in a joint, and it determines at what width the joint must be constructed in order to insure the effectiveness of the sealer. To utilize these procedures one must set forth ahead of time the capabilities of the sealer in terms of three parameters - "X_{max}", "Y_{avg}", and "Z_{min}". Each of the parameters is the ratio of the sealers width of a certain level of compression to its original preformed width "W_n", multiplied by 100. "Z_{min}" is the value of the ratio at the maximum permitted compression of the sealer. "Y_{avg}" is the desired value of the ratio at the time of sealer installation. "X_{max}" is the value of the ratio at the minimum permitted compression of the sealer (enough compression to prevent leakage between sealer and joint face).

For the type of sealers presently available it would appear that "X_{max}" can be no more than 80%, "Z_{min}" should be 40% to 50%, and therefore "Y_{avg}" should be approximately 60%.

The design essentially consists of establishing from Figure A1 the maximum expansion and contraction movements to be experienced at the joint for expected differences between installation deck temperature and subsequent deck temperatures. Using these movements and applying the "X_{max}", "Y_{avg}", and "Z_{min}" values to an estimated sealer size, the construction width of the joint is then determined through a trial and error process.

To illustrate the application of charts Fig. A1 and A2, a solution for a bridge with a span L = 60 ft. is given below.

For New Jersey a concrete temperature range of 0° to 100°F is assumed as being realistic. The wide range of sealer installation and construction temperatures of 30°F to 90°F* is selected with required limits on efficiency coefficients taken as:

$Z_{min} = \pm$ 50% at minimum width of joint ($W_{J_{min}}$) and 100°F.

$Y_{avg} = \pm$ 60% at installation width of joint ($W_{J_{inst}}$) and installation temperature from 30°F to 90°F.

$X_{max} = \pm$ 80% at maximum width of joint ($W_{J_{max}}$) and 0°F.

Step 1. From chart, Fig. A1, using maximum temperature differences between maximum and minimum concrete and of installation temperature ranges Δt = 70°F (100° - 30°) and 90°F (90°-0°), we read off the bridge end movements of Δ= 0.28 in. expansion and 0.36 in. contraction.

Step. 2. By estimating the sealer size W_n = 2.5 in. (Tables A3 & A4) and using the limits $Z = 0.4\ W_n$ and $X = 0.8\ W_n$ we find from chart Fig. A2 that: $W_{J_{min}}$ = 1.25 in., and $W_{J_{max}}$ = 2.00 in.

$$\frac{W_{J_{max}} - W_{J_{min}}}{2} = \frac{0.75}{2} = 0.375 \text{ in.} > 0.36 \text{ in. (max. joint movement).}$$

Thus, the joint construction width should be:

$W_{J_{constr.}}$ = 1-1/2" with $Y_{instal.} = 0.60\ W_n$

The width of joint ($W_{J_{constr.}}$) is measured at the upper portion of the joint where the sealer is located.

(Approximate place for Figs. A1 and A2 and Tables A3 and A4)

(*) The installation temperature range between 30°F and 90°F is selected as the only realistic approach to the existing construction practices.

GUIDE "B"

CONSTRUCTION PROCEDURE FOR ARMORED JOINTS

The concept of this method is that the entire system (armor plates with straps and seats welded to them, sealer properly precompressed between the plates and the supporting elements, such as clamps and attached bolts) is preassembled and then placed into the joint before the concrete is poured.

There are many ways of doing the above. The procedure used should satisfy the design requirements on the one hand, and on the other, it must give the fullest possible consideration to the de facto construction practices.

On this basis, the best approach would be to have the elements of the system preassembled to the fullest practicable degree, delivered to the construction site and there the assembly completed. The deck should be poured so as to leave the necessary recess with deck reinforcement properly extended into it. After the concrete is set, the assembly can be placed into the recess, properly located, and the width of the joint between the armor plates adjusted in accordance with the design requirements; then the bar-straps should be welded to the main deck reinforcement. The recess should be filled to the level "A" (Fig. B4) with optimum-packed-up concrete of good quality. After the concrete in the recess is set, the supporting elements should be removed and the surfacing of the deck at the joint carefully completed.

This procedure, with a little care in construction, should give a satisfactorily sealed joint.

The armored deck joints should be continuous throughout the full width of the deck, and termination should be accomplished as shown in Figs. B2 through B5. It is obvious that the armor is utilized for a dual purpose: to armor the joints where necessary, and to form the best sealed joint possible.

The seal-groove in the sidewalk should also be armored in the same manner, with the curb and outside ends installed as shown in Figures B1 through B5, but a stay-in-place anchor seat could be added in the curb end at the bottom outside face of the armor shapes.

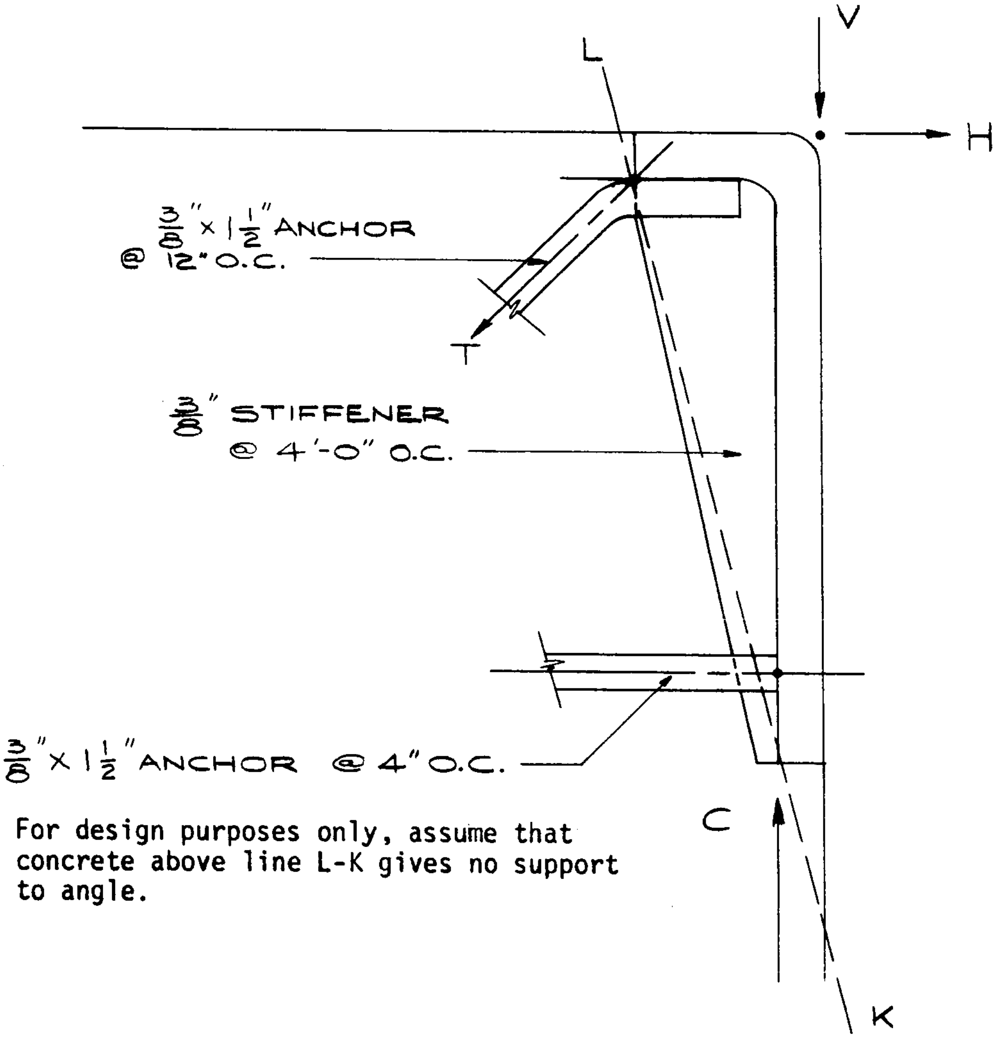
All steel of the armor network should be painted. In addition it is recommended that the armor be of ASTM A-242 steel. The stable rust characteristics of this material will serve advantageously in those areas where paint is likely to deteriorate rapidly with traffic.

Standard lubricant-adhesive shall be applied on both sides of the sealer when located in the armor.

(Approximate place for Figures B1 through B5)

GUIDE "C"

ARMORED JOINT DESIGN



For design purposes only, assume that concrete above line L-K gives no support to angle.

LOADS

For reference please see AASHO, 1965 (or latest edition, if available), paragraph 1.2.5 (HS 20-44):

Concentrated Loads (for shear):	26.0 kips
Wheel load (for horizontal shear):	16.0 kips

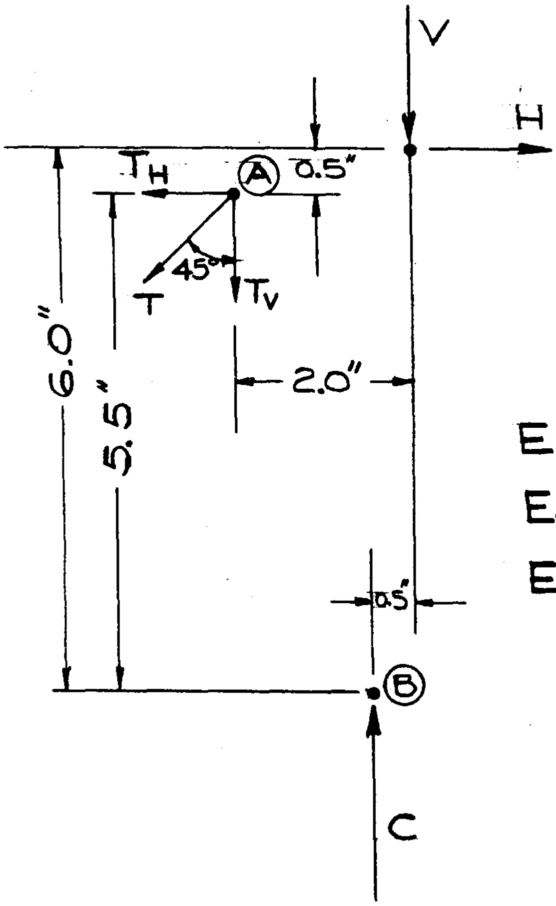
paragraph 1.2.12(C) Impact fraction: 30%

Friction factor for horizontal load: 0.75

paragraph 1.3.2(H) Cantilever Slabs:

Moment per foot of slab $= \frac{P}{E}X$;

Case B: E $= 0.35\ X + 3.2$;



$V = 26.0 + 0.3 \times 26.0 = 33.8\ K/E$

$H = 16.0 \times 0.75 = 12.0\ K/E$

LOAD DISTRIBUTION

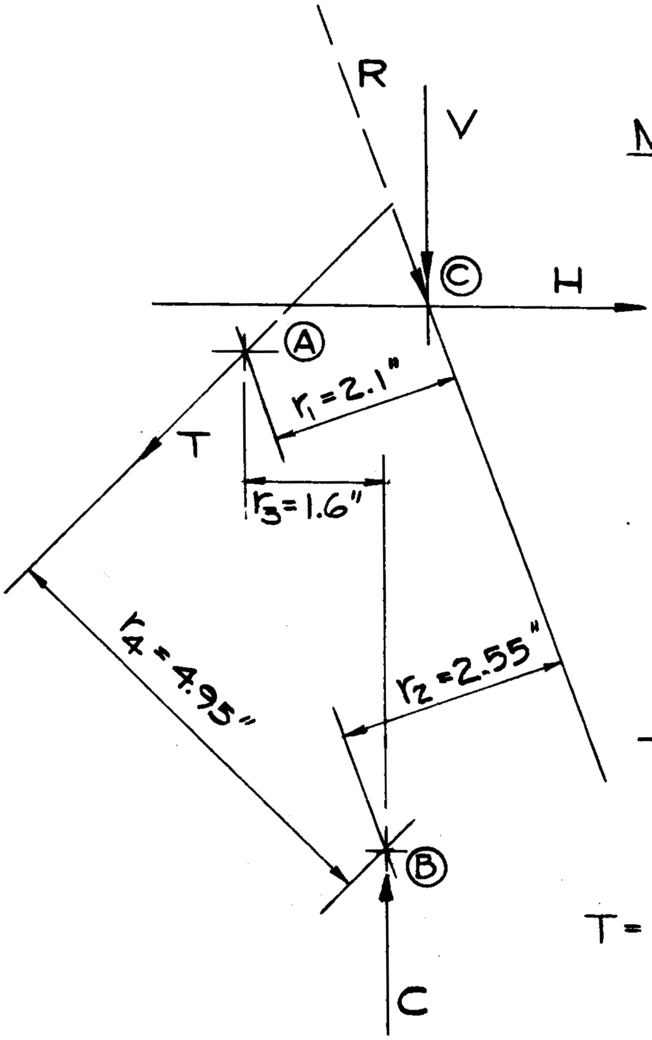
$E_1 = 0.35 \times 0.5 + 3.2 = 3.375$ FT.

$E_2 = 3.2$ FT.

$E_3 = 0.35 \times 0.17 + 3.2 = 3.26$ FT.

In absence of definite guidelines I am exercising my judgment in making reasonably severe assumptions. This is what W. Koester said about it in his previously referred book (4):

"The severity of the forces acting on the edges of the joint increases with the gap width. This necessitates the provision of a steel edge-protection strip which must be so rigid and so closely anchored that it forms an indissoluble composite structure with the bridge deck. The prerequisite for this is that the steel components should be securely joined to the concrete at all contact surfaces."



$$R = \sqrt{V^2 + H^2}$$

MOMENT ABOUT SUPPORT "A" :

$$R \times r_1 - C \times r_3 = 0$$

$$C = \frac{r_1}{r_3} \times R = \frac{r_1}{r_3} \times \sqrt{V^2 + H^2} \quad ;$$

$$C = \frac{2.1}{1.6} \sqrt{\left(\frac{33.8}{3.375}\right)^2 + \left(\frac{12.0}{3.20}\right)^2} \quad ;$$

$$C = 14.03 \text{ K/FT.}$$

MOMENT ABOUT SUPPORT "B"

$$R \times r_2 - T \times r_4 = 0$$

$$T = \frac{r_2}{r_4} R = \frac{r_2}{r_4} \sqrt{V^2 + H^2} \quad ;$$

$$T = \frac{2.55}{4.95} \sqrt{\left(\frac{33.8}{3.2}\right)^2 + \left(\frac{12.0}{3.26}\right)^2} \quad ;$$

$$T = 5.77 \text{ K/FT.}$$

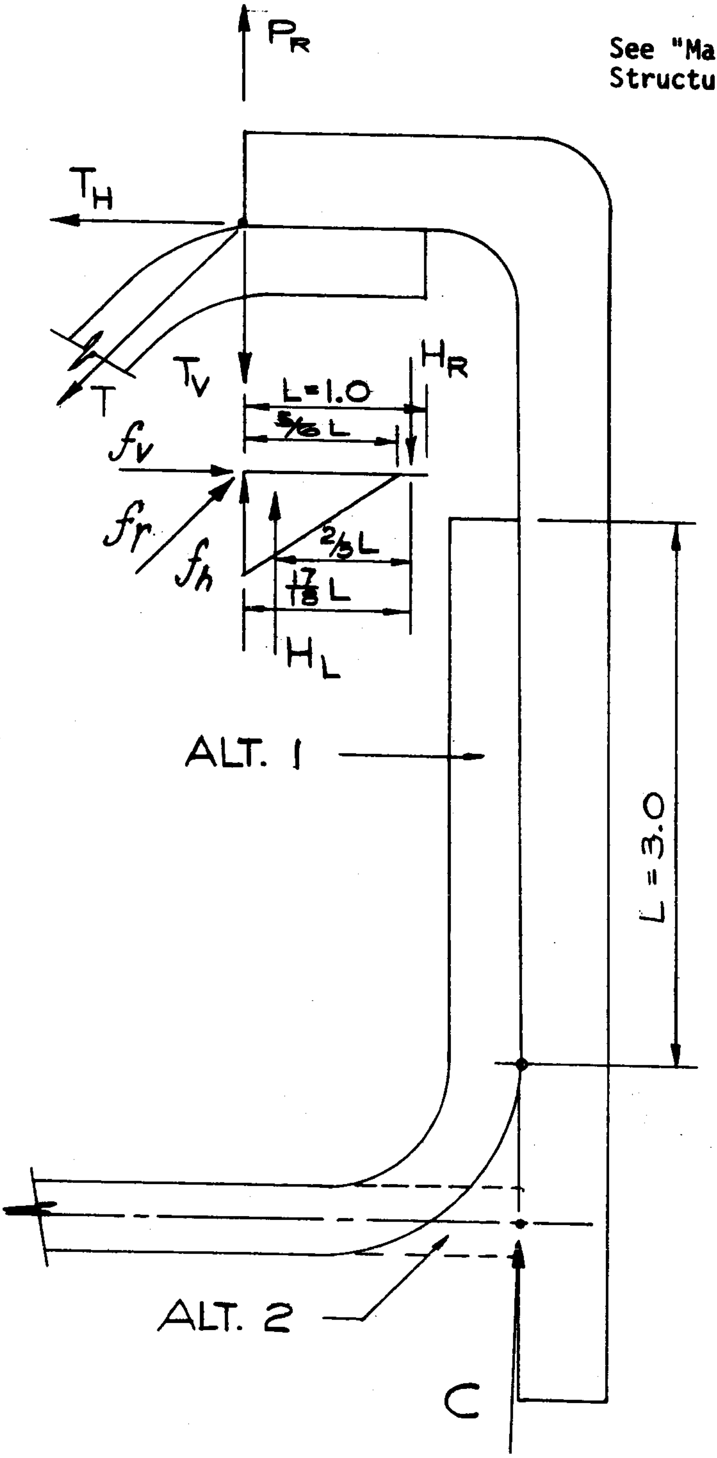
IF: $T = \sqrt{T_V^2 + T_H^2}$

AND $T_V = T_H$ (@ 45°)

THAN: $T_V = T_H = 0.707T = 4.08$ K/FT.

WELDING STRESSES

See "Manual of Design for ARC Welded Steel Structures" Air Reduction, N.Y. (9)



$$H_L = H_R = H = \frac{5}{12} f_h L \;;$$

$$P_r = 0.707 f_{ALL} D L_1$$

$$(T_V - P_r) \times \frac{17}{18} L = H_L \times \frac{2}{3} L$$

THEREFORE:

$$f_h = \frac{17}{5L}\left(T_V - 0.707 f_{ALL} D L_1\right) \;;$$

$$f_V = \frac{T_H}{2L + L_1} \;;$$

$$f_r = \sqrt{f_h^{\,2} + f_V^{\,2}} \;;$$

FOR ANCHORS @12"O.C.:

$T_V = 4.08_K$

$L_1 = 1.5''$ (WIDTH OF STRAP)

$L = 1.0''$

$D = \frac{5}{16}''$ (SIZE OF WELD)

$f_r = 0.707 f_{ALL}.D \;;$

$$f_h = \frac{17}{5 \times 1.0}(4.08 - 0.331 f) = 13.85 - 1.13 f$$

$$f_V = \frac{4.08}{3.5} = 1.17$$

$$0.221 f = \sqrt{(13.85 - 1.13 f)^2 + 1.17^2}$$

$f = 10.7\ {}^{K}/_{\square''^2} < f_{\dots}$

ALTERNATE 1, ANCHORS @ 12" O.C.

$$0.707 \times f \times D \times 2L = C$$

$$f = \frac{C}{1.41 \times D \times L} = \frac{14.03}{0.442L} = \frac{31.8}{L} ;$$

FOR $L = 3.0$ in. EACH SIDE :

$$f = \frac{31.8}{3.0} = 10.6\ \text{K}/\text{in}^2 < f_{ALL}.$$

BEARING

AVAILABLE $L = 9.0$ in.

ASSUMING TRIANGULAR BEARING DISTRIBUTION:

BEARING STRESS SHALL BE :

$$f_{BEAR.} = \frac{C}{A} = \frac{C}{1.5 \times \frac{L}{2}} = \frac{2C}{1.5L} = \frac{2 \times 14.03}{1.5L} = \frac{18.73}{L}$$

$$f_{BEAR.} = \frac{18.73}{9.0} = 2.08\ \text{K}/\text{in}^2 > f_{ALL}.$$

ALTERNATE 2, "n" ANCHORS (WELDING STRESSES)

$$0.707 f \times D \times 2(a+b) \times n = C$$

$$f = \frac{C}{0.707 \times D \times 3.75 \times n} = \frac{14.03}{0.83 \times n} = \frac{16.95}{n} ;$$

FOR $n = 2$ OR @ 6 in. O.C. :

$$f = \frac{16.95}{2} = 8.5\ \text{K}/\text{in}^2 < f_{ALL}.$$

SHEAR STRESSES :

$$f_{SH} = \frac{C}{A \times n} = \frac{14.03}{0.375 \times 1.5 \times n} = \frac{25.0}{n} ;$$

FOR $n = 2$:

$$f_{SH} = \frac{25.0}{2} = 12.5\ \text{K}/\text{in}^2 < f_{ALL}.$$

BEARING (ALTERNATE 2)

AVAILABLE L = 10.5 in.

$$f_{BEAR} = \frac{C}{1.5 \times \frac{L}{2} \times n} = \frac{2 \times C}{1.5 \times L \times n} = \frac{2 \times 14.03}{1.5 \times 10.5 \times n} = \frac{1.78}{n};$$

FOR $n = 3$ OR @ 4 in O.C. :

$$f_{BEAR} = \frac{1.78}{3} = 0.593\ {}^{K}/_{in^2} < f_{ALL}.$$

USE: BOTTOM ANCHORS @ 4 in O.C.

TENSION STRESSES IN TOP ANCHORS:

$$f_T = \frac{T}{A} = \frac{5.77}{0.375 \times 1.5} = 10.28\ {}^{K}/_{in^2} < f_{ALL}.$$

BOND STRESSES:

ASSUMING THAT HOOK SHALL DEVELOP 50% OF THE ALLOWABLE STRESS IN THE STRAP, THE BOND STRESS SHALL BE:

$$f_{BOND} = \frac{T}{2\,(a+b)\,L \times 2} = \frac{5.77}{7.5 \times L} = \frac{0.77}{L};$$

FOR L = 7"

$$f_{BOND} = \frac{0.77}{7.0} = 0.11\ {}^{K}/_{in^2} < f_{ALL}$$

Headers

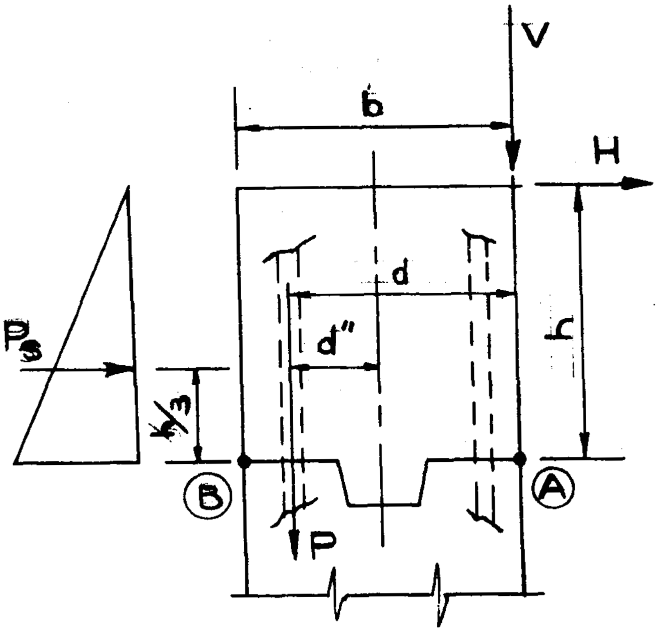
Before concluding this article, it is imperative that problems and design associated with headers should be at least aired here.

Failure of headers is not uncommon and has been observed personally by the researcher. It is believed that causes for their failure are as follows:

1. Loading, such as indicated in armor design.
2. Inadequate preparation of the backfill.
3. Concrete approach slabs directly supported by headers.

For the second problem, only one remedy can be suggested -- improvement of quality control in construction.

DESIGN (suggested approach):



Again as before:

Concentrated loads: 26.0 kips

Wheel loads for horizontal shear: 16.0 kips

Impact fraction: 30%

Friction factor for tire against concrete: 1.0

CANTILEVER SLABS :

MOMENT PER FOOT OF SLAB $= \frac{P}{E} X$;

WHERE $E = 0.35X + 3.2$;

THUS : $V = 33.8\ ^{K}/_{E}$

$H = 16.0 \times 1.0 = 16.0\ ^{K}/_{E}$.

LOAD DISTRIBUTION :

$E = 0.35 \times 1.5 + 3.2 = 3.725$ FT.

MOMENT ABOUT PLANE "A-B" :

$$M = \frac{33.8}{3.725} \times \frac{b}{2} + \frac{16.0}{3.725} \times h + P_S \times \frac{h}{3} ;$$

TOTAL VERTICAL LOAD IS :

$$N = \frac{33.8}{3.725} + 0.15 \times 1.5^2 \times 1.0 ;$$

REINFORCEMENT DESIGN (10):

$$e = \frac{12 \times M}{N} + d''\text{(in.)}$$

$$P = \frac{N(e - jd)}{jd} \quad (^{K}/_{\text{FT. WIDTH}})$$

Although the stresses in the vicinity of point "A" due to moving loads, are somewhat smaller, it is suggested to use the same reinforcement on both sides of a header.

A few words about approach slabs seem warranted before concluding this analysis. The problem of approach slabs is a very complex one, especially if a rigid slab is supported on one end elastically, and on the other end off a vertically rigid but horizontally flimsy support such as a header.

In such a case the effect on a header would be vertically an eccentrically located static load and a distinctly possible substantial horizontal static force, and of course dynamic reactions in addition to those already discussed.

In this paper the problem of approach slabs and pertinent remedies shall not be further discussed since the prime purpose of this work is the sealing of joints. However, it must be said that a joint which is not permitted to function as designed cannot be sealed. Even a perfect solution of the joint sealing problem will be useless if a header failure, from whatever cause, disallows proper functioning of the joint.

In the experimental bridges, approach slabs were removed, but also grossly inadequate preparation of the backfill had to be combated.

In conclusion it should be stated that the design and construction of armor anchorage and headers is a very serious problem which to date is apparently being sometimes taken too lightly. The suggestions above offered should serve to air the related problems and perhaps help to alleviate them.

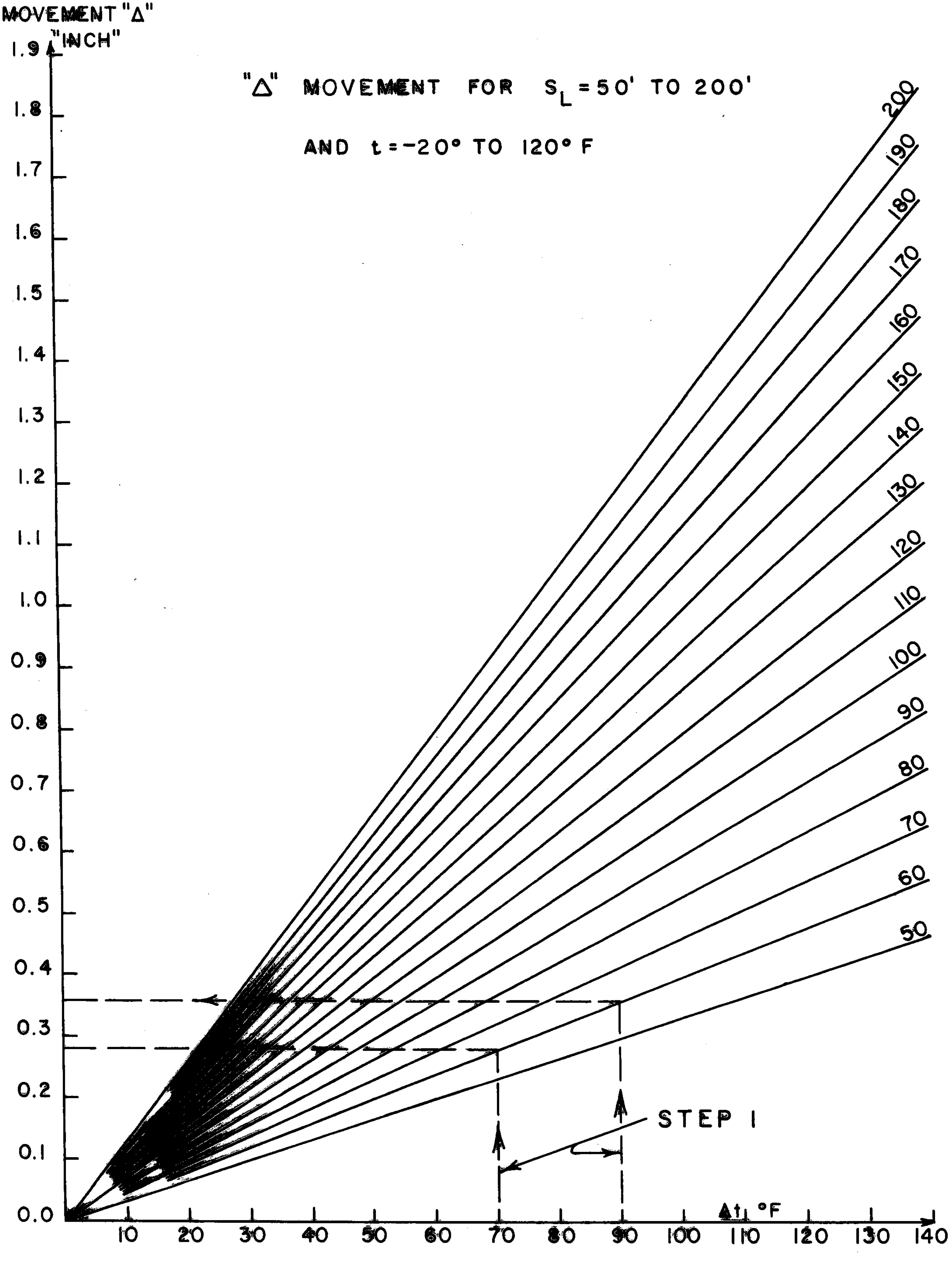

MOVEMENT "Δ" "INCH"
"Δ" MOVEMENT FOR S_L = 50' TO 200'
AND t = -20° TO 120° F
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
STEP I
Δt, °F
10
20
30
40
50
60
70
80
90
100
110
120
130
140

FIG. A-1

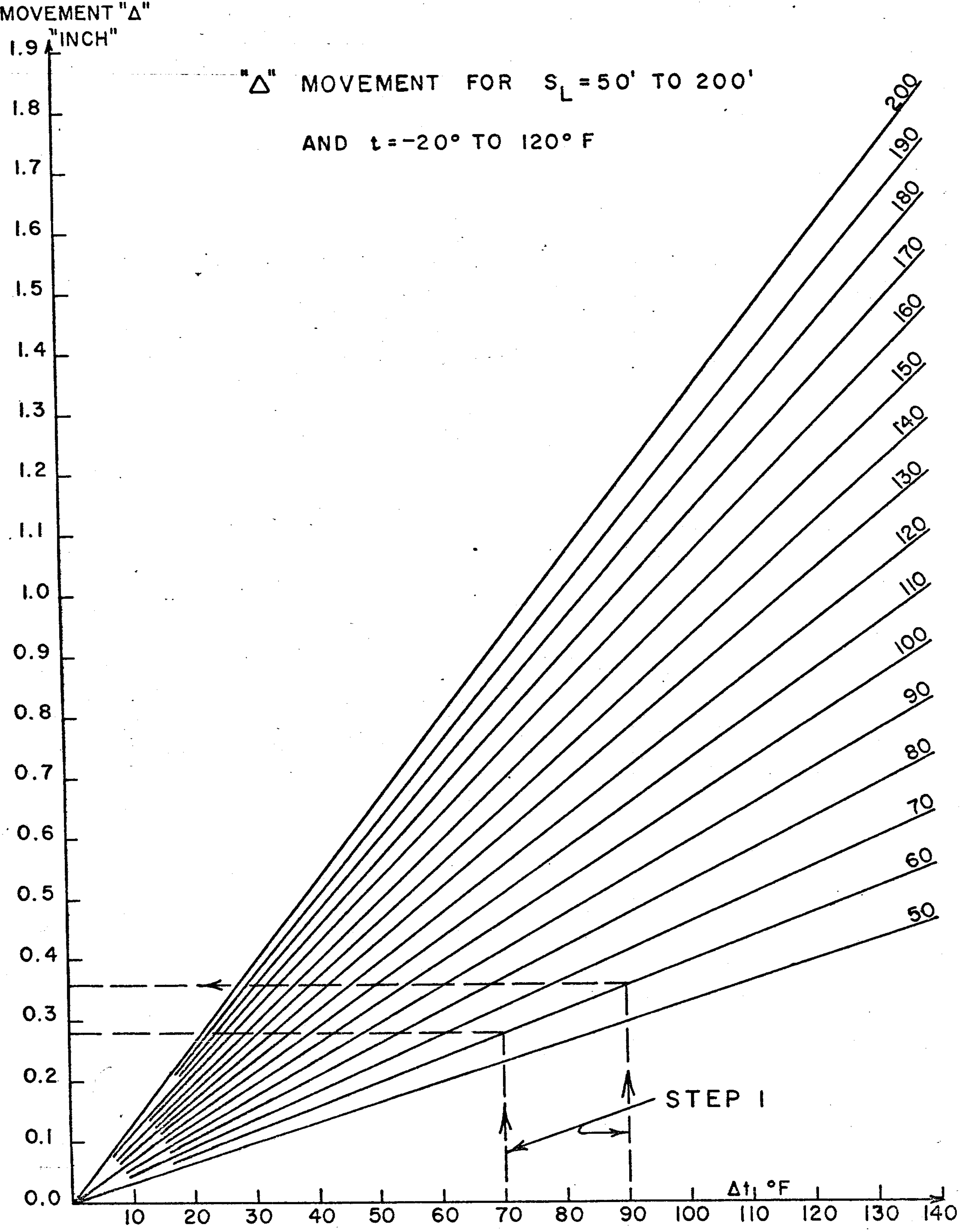

"Δ" MOVEMENT FOR $S_L = 50'$ TO 200'
AND t = -20° TO 120° F
MOVEMENT "Δ"
"INCH"
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Δt₁ °F
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
STEP I

FIG. A-1

JOINT SEALER EFFICIENCY CHART

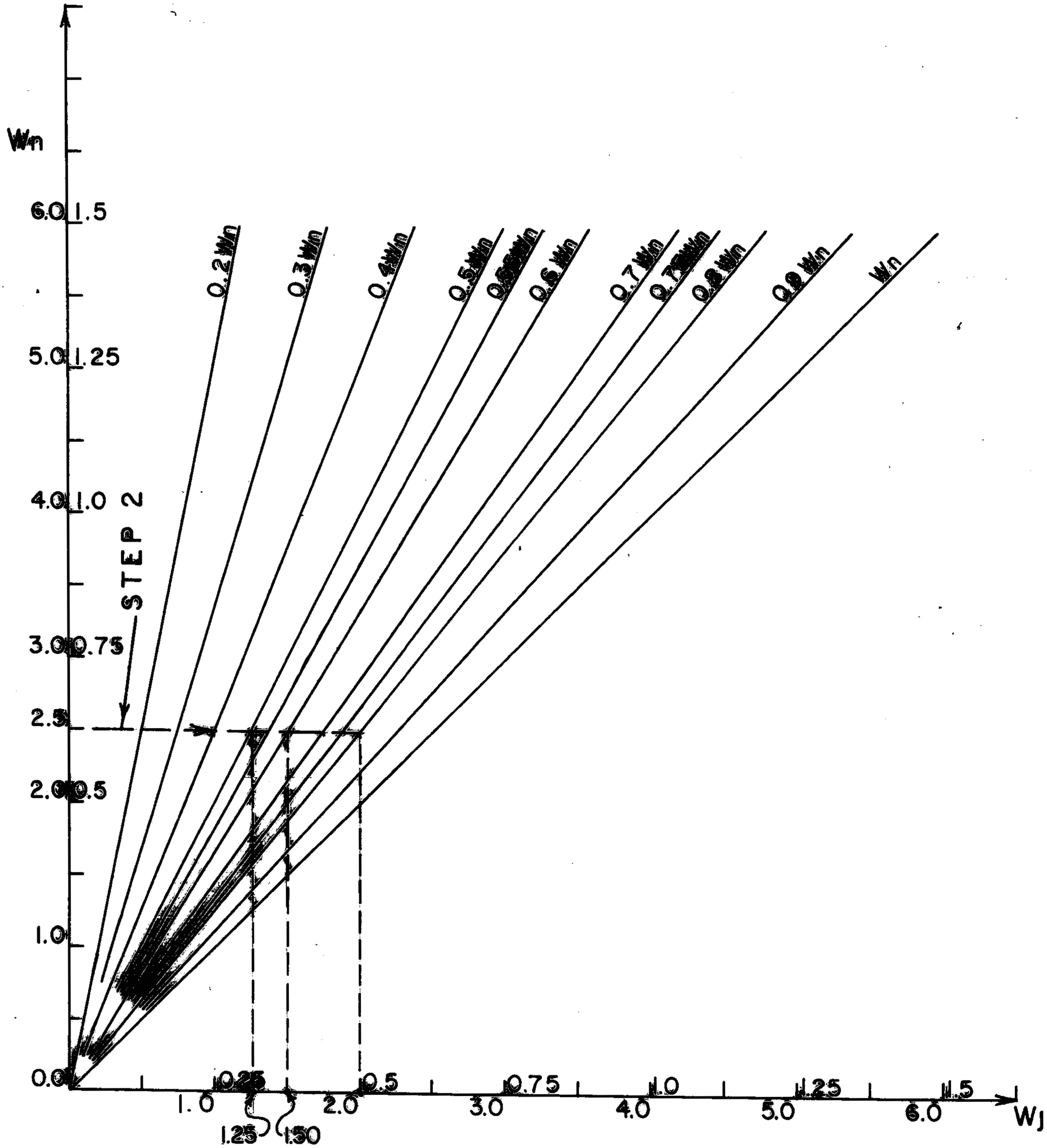


FIG. A2

G.S. KOZLOV

JOINT SEALER EFFICIENCY CHART

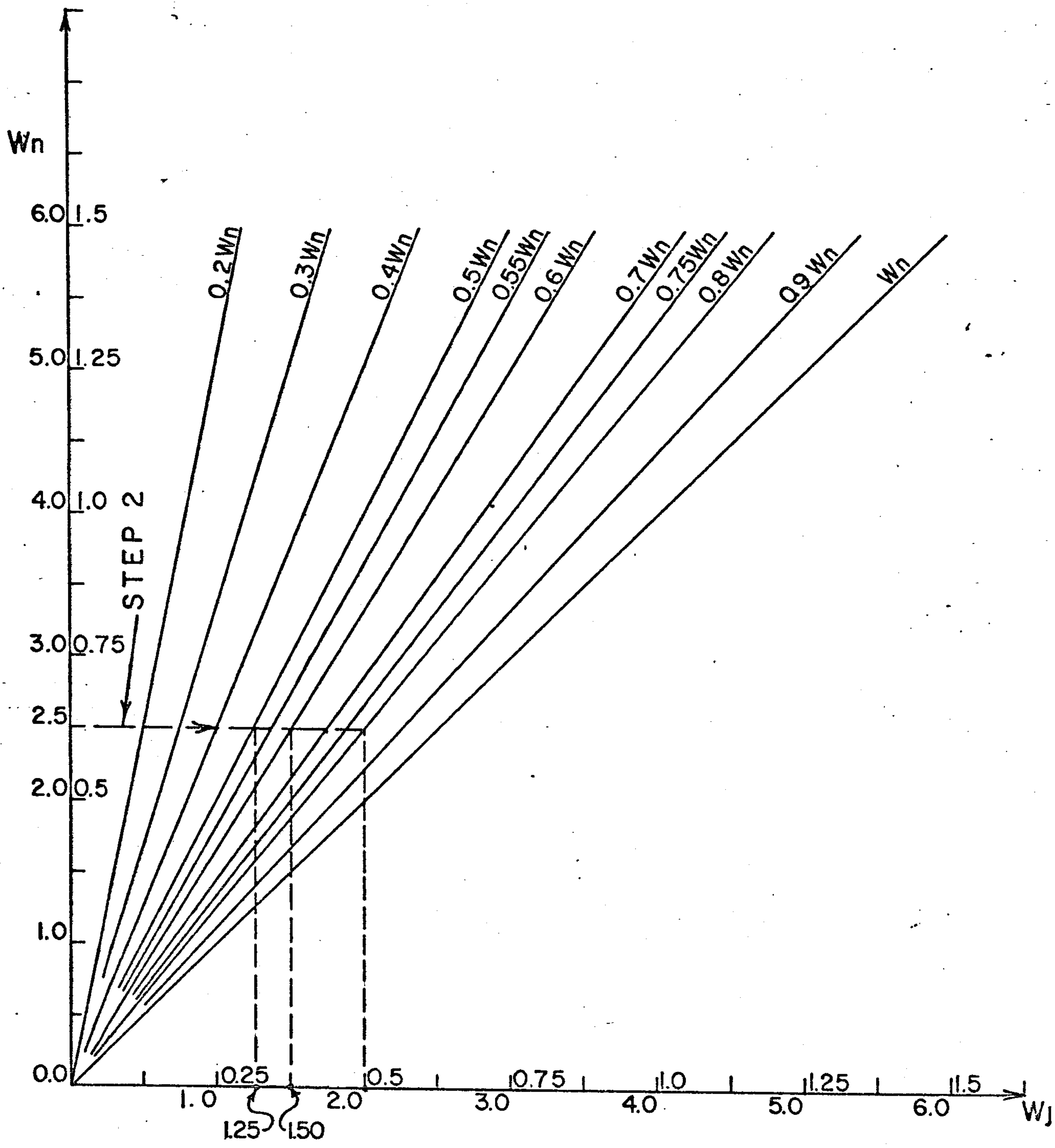


FIG. A2

Table A 3
Guide to the design of sealers

Temperature Range: 0° to 100°F
Construction Temperature: 30° to 90°F
Installation Temperature: 30° to 90°F
Degrees of Efficiency: $Z_{min} = \pm 0.50\ W_n$
$Y_{average} = \pm 0.60$ to $0.65\ W_n$
$X_{max} = \pm 0.80\ W_n$

	@100°F		Δ @	@30° to 90°F		Δ @	@ 0°F		Limits
W_n	$W_{j\,min.}$	Z	Δt=70°	W_j	Y	Δt=90°	$W_{j\,max.}$	X	of Span
1 1/2"	0.875	0.58	0.00	7/8"	0.58	0.00	0.875	0.58	**Up to 40'**
	0.695	0.46	0.18			0.24	1.115	0.74	
1 3/4"	0.945	0.54	0.18	1 1/8"	0.64	0.24	1.365	0.78	**40' to 45'**
	0.915	0.52	0.21			0.27	1.395	0.80	
2"	1.04	0.52	0.21	1 1/4"	0.625	0.27	1.52	0.76	**45' to 55'**
	1.00	0.50	0.25			0.33	1.58	0.79	
2 1/2"	1.25	0.50	0.25	1 1/2"	0.60	0.33	1.83	0.73	**55' to 70'**
	1.18	0.47	0.32			0.42	1.92	0.77	
3"	1.555	0.52	0.32	1 7/8"	0.625	0.42	2.295	0.765	**70' to 90'**
	1.455	0.485	0.42			0.53	2.405	0.80	
4"	2.08	0.52	0.42	2 1/2"	0.625	0.53	3.03	0.76	**90' to 120'**
	1.95	0.49	0.55			0.71	3.21	0.80	
5"	2.575	0.515	0.55	3 1/8"	0.625	0.71	3.835	0.77	**120' to 150'**
	2.435	0.49	0.69			0.89	4.015	0.80	
6"	3.06	0.51	0.69	3 3/4"	0.625	0.89	4.64	0.77	**150' to 180'**
	2.92	0.49	0.83			1.07	4.82	0.80	

NOTE: All the above temperatures are those of the concrete. Since these temperatures cannot readily be measured, the daily average temperature of the air with a tolerance of +5 to +10°F would be presently acceptable.

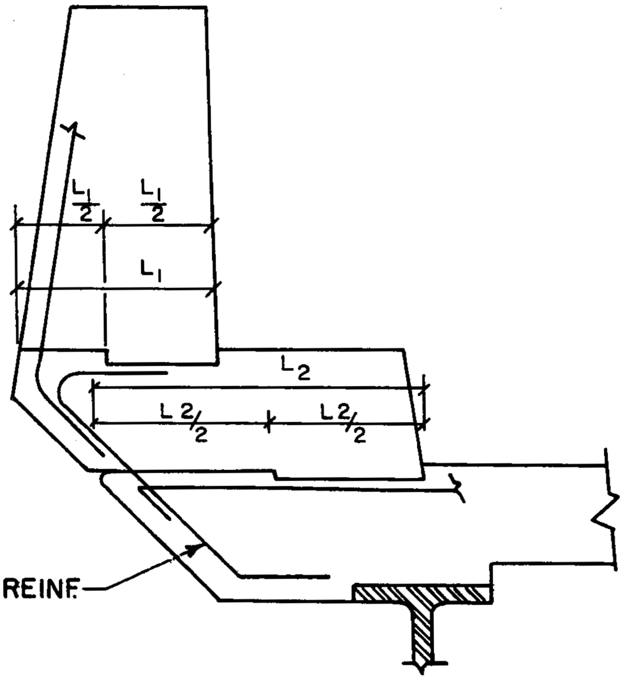
TABLE A4

GUIDE TO THE DESIGN OF SEALERS

Temperature Range: 0° to 100°F
Construction Temperature: 30° to 90°F
Installation Temperature: 30° to 90°F
Degrees of Efficiency: $Z_{min} = 0.40\ W_n \pm$
$Y_{average} = 0.60\ W_n \pm$
$X_{max} = 0.80\ W_n \pm$

	@100°F		Δ@	@30° to 90°F		Δ@	@ 0°F		Limits
W_n	$W_{j\,min.}$	Z	$\Delta t=70°$	W_j	Y	$\Delta t=90°$	$W_{j\,max.}$	X	of Span
1½"	0.875	0.58	0.0	7/8"	0.58	0.0	0.875	0.58	Up to
	0.621	0.41	0.254			0.327	1.202	0.80	55.0'
$1\frac{3}{4}$"	0.746	0.43	0.254	1"	0.57	0.327	1.327	0.75	55.0' to
	0.700	0.40	0.300			0.386	1.386	0.79	65'
2"	0.825	0.41	0.300	1-1/8"	0.56	0.386	1.511	0.76	65.0' to
	0.778	0.39	0.347			0.446	1.571	0.79	75'
2½"	1.153	0.46	0.347	1½"	0.60	0.446	1.946	0.78	75' to
	1.084	0.43	0.416			0.535	2.035	0.81	90'
3"	1.334	0.44	0.416	1-3/4"	0.58	0.535	2.285	0.76	90' to
	1.242	0.41	0.508			0.653	2.403	0.80	110'
4"	1.867	0.47	0.508	2-3/8"	0.59	0.653	3.028	0.75	110' to
	1.682	0.42	0.693			0.891	3.266	0.81	150'
5"	2.182	0.44	0.693	2-7/8"	0.57	0.891	3.766	0.75	150' to
	1.951	0.39	0.924			1.188	4.063	0.81	200'
6"	2.576	0.42	0.924	3½"	0.58	1.188	4.688	0.78	200' to
	2.484	0.41	1.016			1.307	4.807	0.80	220'

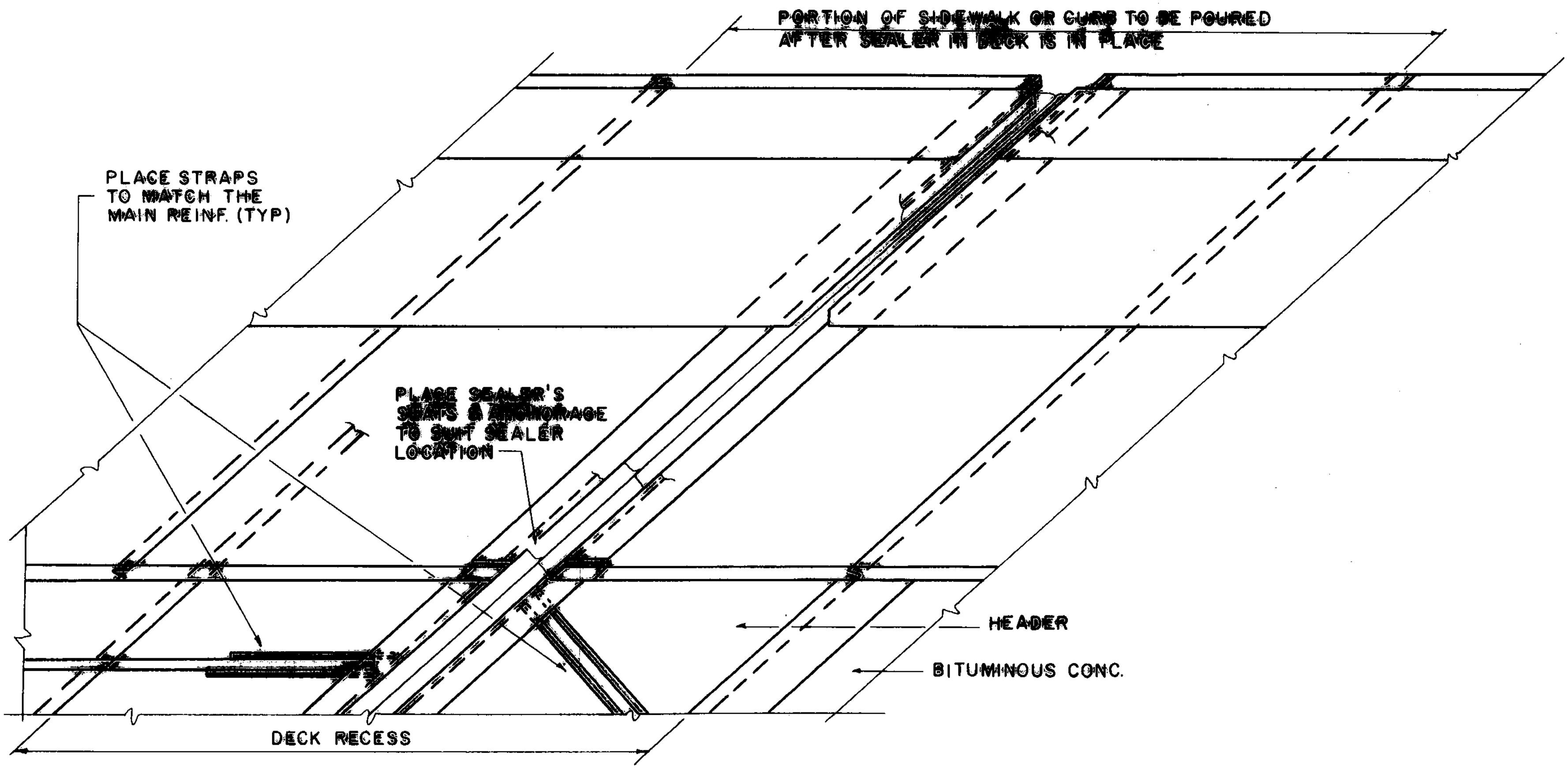
NOTE: All the above temperatures are those of the concrete. Since these temperatures cannot readily be measured, the daily average temperature of the air with a tolerance of +5 to +10°F would be presently acceptable.



TYPICAL PROPOSED DESIGN
FOR CURB - SIDEWALK - PARAPET
DETAIL FOR BRIDGES

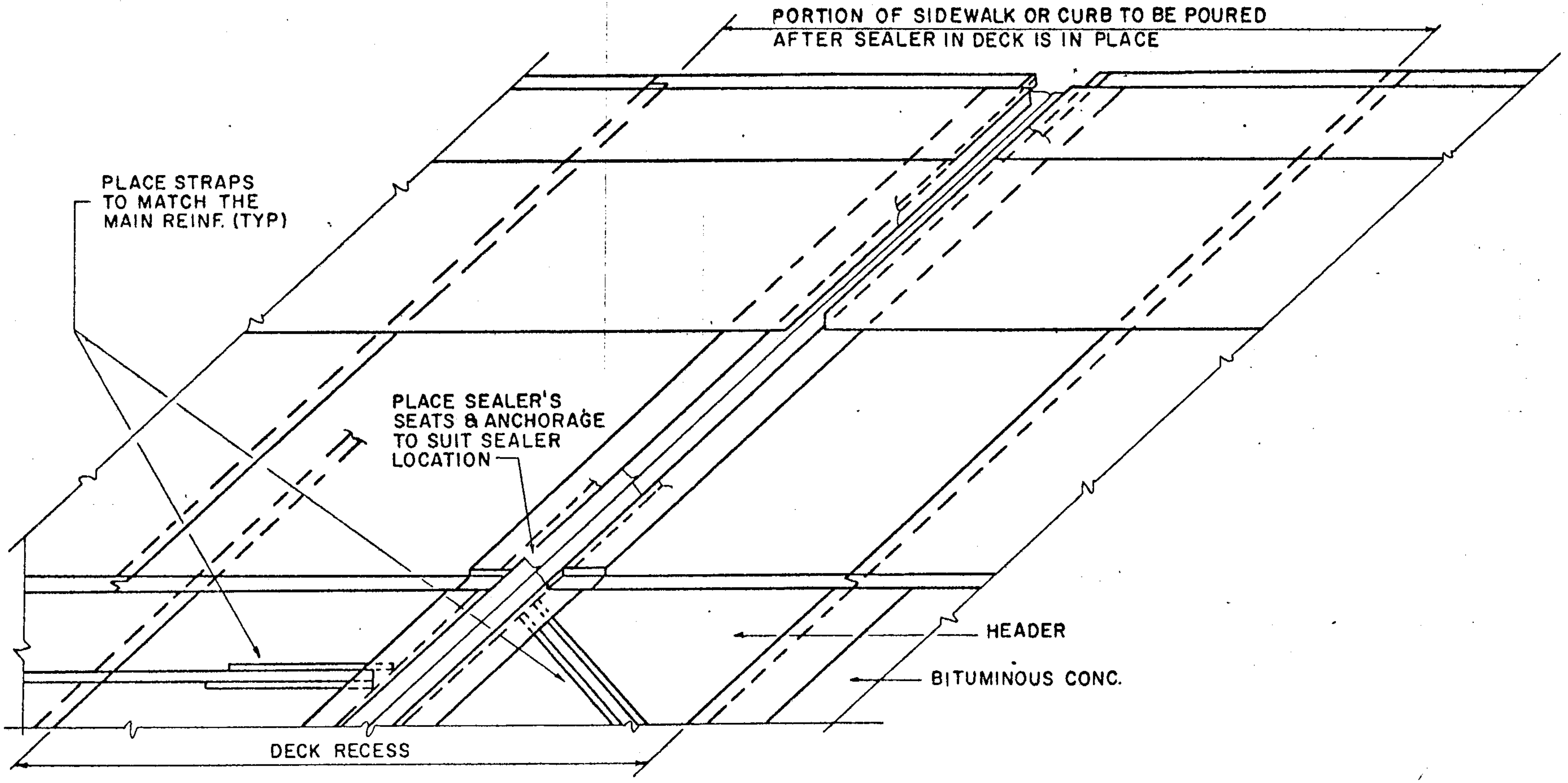
NOTE: Could be used throughout but is absolutely necessary at joints.

FIG. B-1



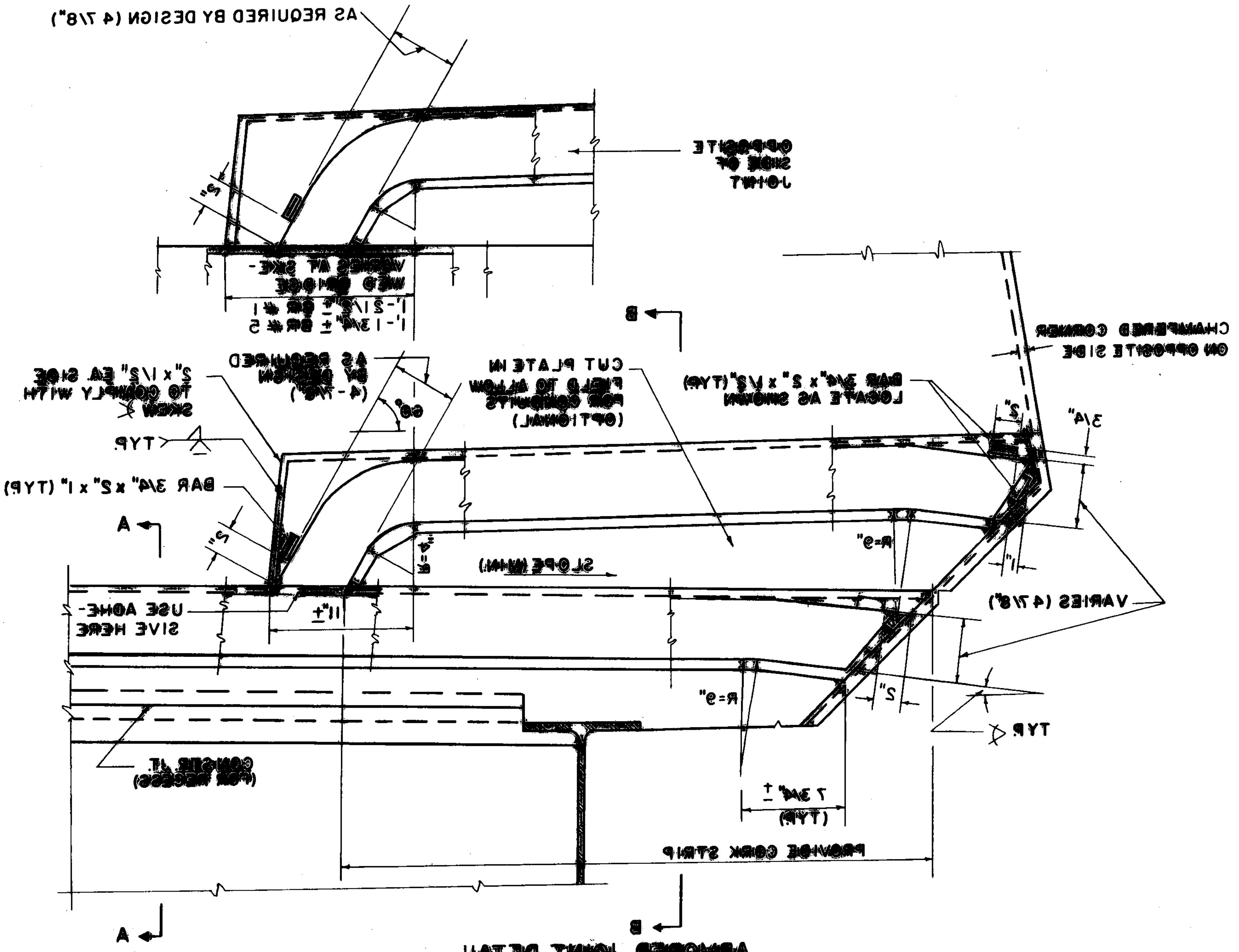
TYPICAL JOINT DETAIL
AT SIDEWALKS AND CURBS

FIGURE B2

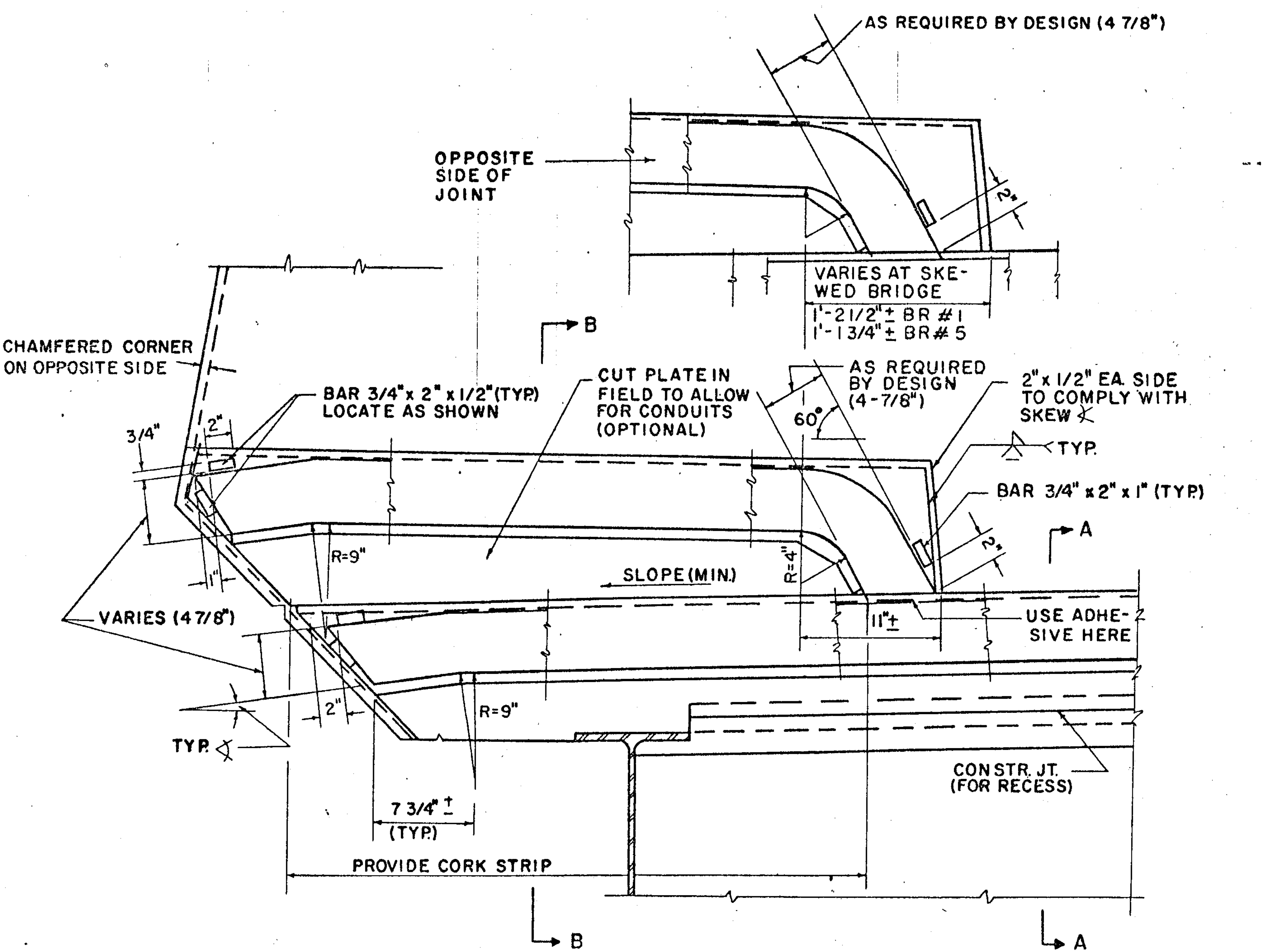


TYPICAL JOINT DETAIL
AT SIDEWALKS AND CURBS

FIGURE B2

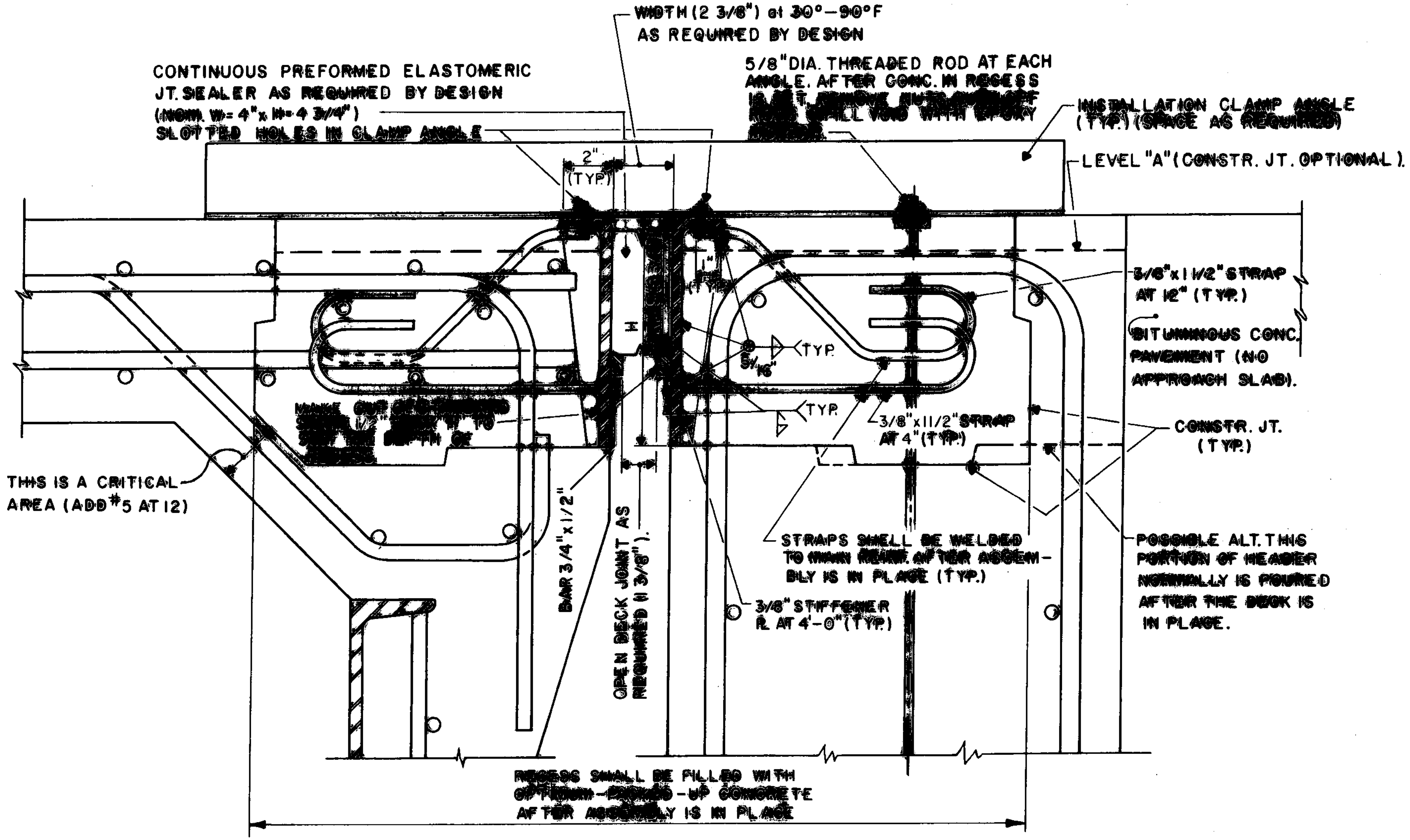


ARMORED JOINT DETAIL
]



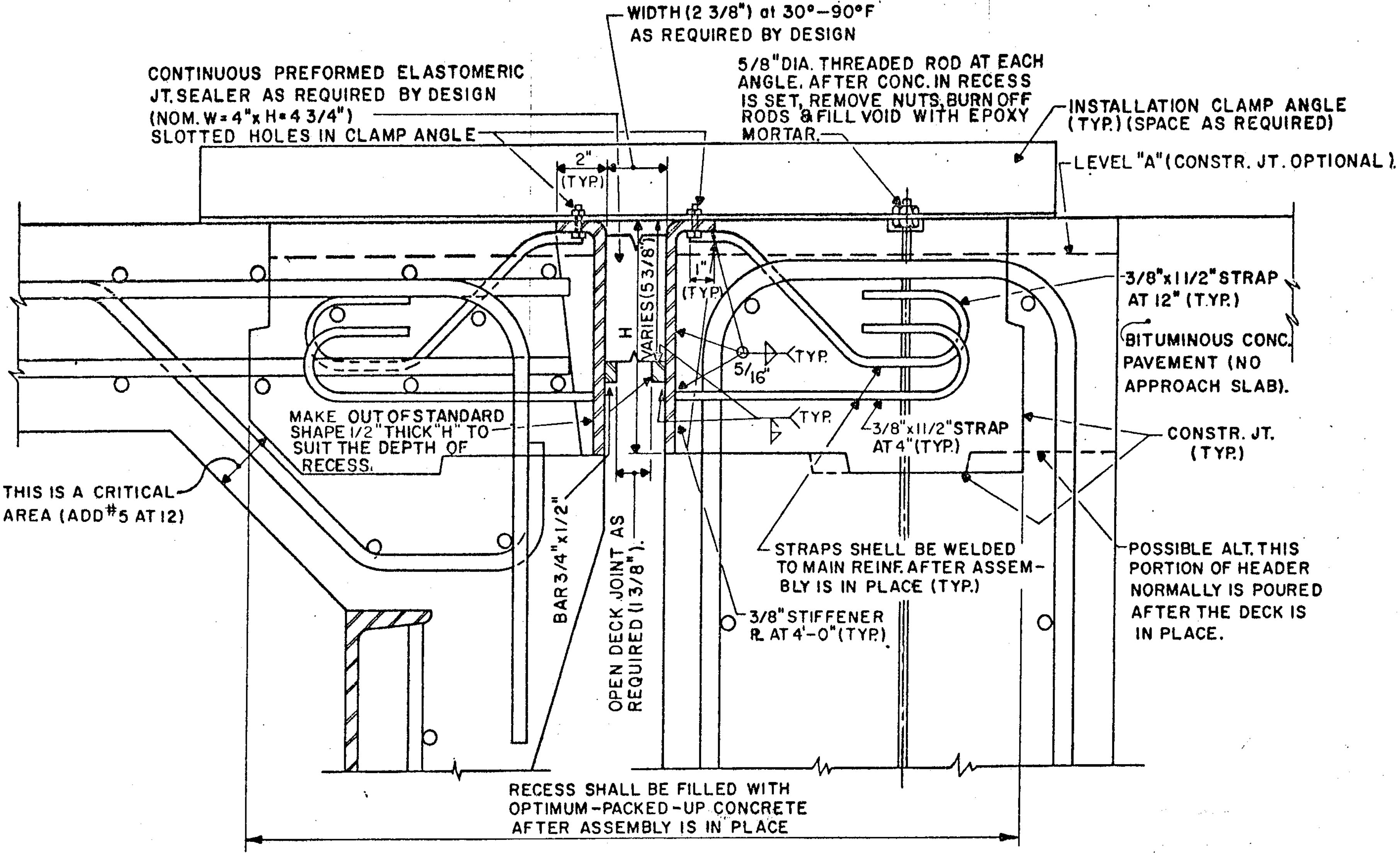
ARMORED JOINT DETAIL
SAFETY WALK & CURB LOCATION

FIGURE B3



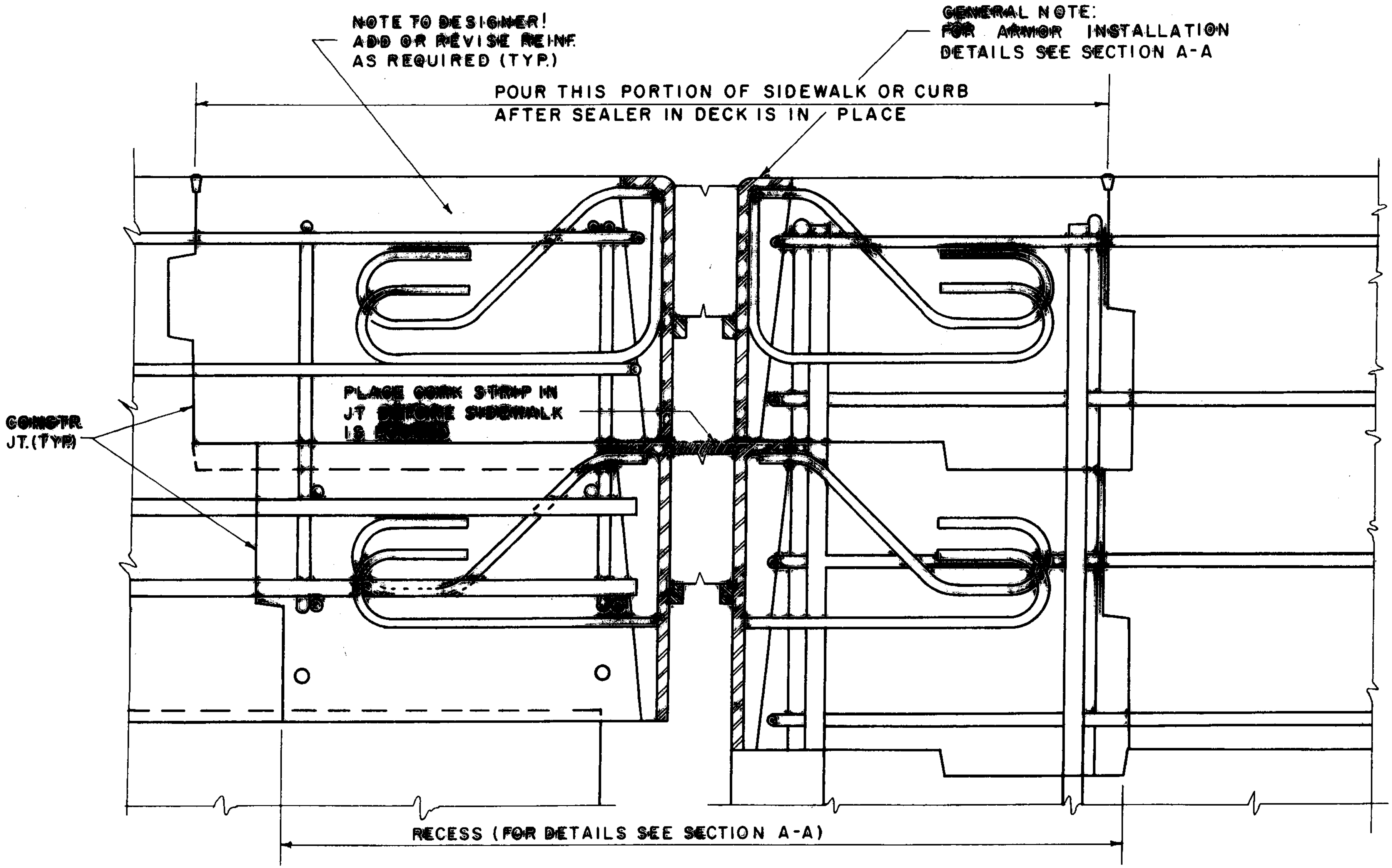
ARMORED JOINT DETAIL
SECTION A-A

FIGURE B4



ARMORED JOINT DETAIL
SECTION A-A

FIGURE B4



SECTION B-B

FIGURE B 5

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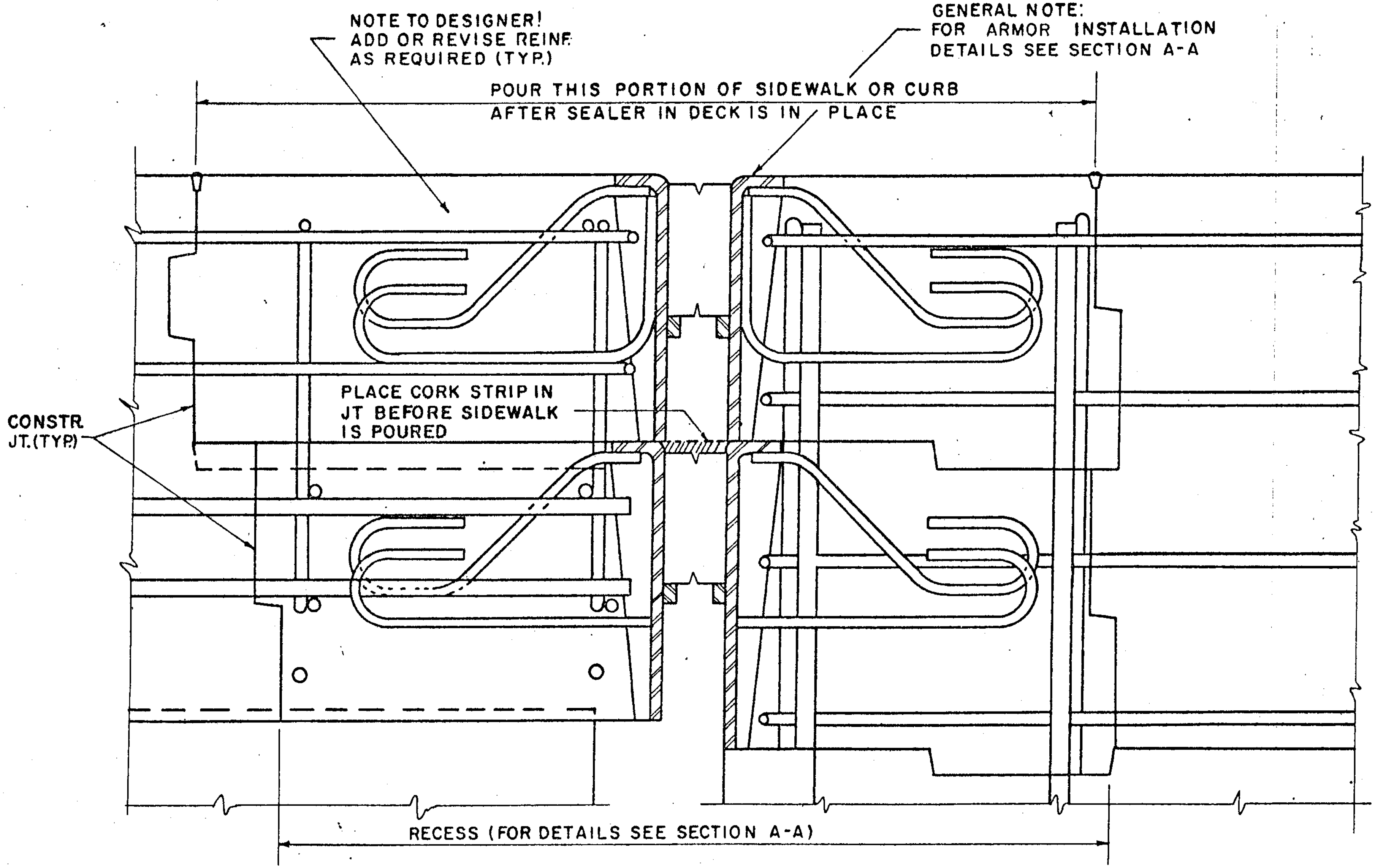

SECTION B-B

FIGURE B 5