STRUCTURAL CONCRETE

INSPECTOR'S SCHOOL

PART I
SMALL STRUCTURES

PART II
LARGE STRUCTURES

TEXAS HIGHWAY DEPARTMENT
DISTRICT 12

1963

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<u>PART I - SMALL STRUCTURES</u>

I. <u>General</u>

A. <u>Definition of Concrete</u>

Item 421.1, page 413, of the Standard Specifications states that "concrete shall be composed of portland cement, mineral filler, if necessary, natural aggregates (fine and coarse) and water, proportioned and mixed as hereinafter provided in these specifications." On page 7 of <u>Texas Highway Department Construction Bulletin C-11</u>, in the last paragraph, the following statement appears: "Concrete has been defined as a mixture of coarse aggregate, fine aggregate, cement, and water."

Actually, a simple definition of concrete is not enough. In order to understand clearly the interrelation of design factors, it becomes necessary to acquire a new conception of concrete and to visualize the component parts of the mixtures as follows:

"Concrete" is composed of two ingredients, "coarse aggregate" and "mortar." The mortar not only fills the voids in the coarse aggregate, but separates the coarse aggregate particles. It may be said that the mortar lubricates the coarse aggregate.

"Mortar" is composed of two ingredients, "fine aggregate" or "sand" and "paste." The paste not only fills the voids in the sand, but separates the sand particles. It may be said that the paste lubricates the sand.

"Paste" is composed of two ingredients, "cement" and "water." The proportions of cement and water determine the strength of the paste and the consistency of the paste or its value as a lubricant.

B. Component Materials of Concrete

From the above description or definition of concrete, it is seen that concrete is composed of portland cement, coarse aggregate, fine aggregate and water.

The cement may be either Type I, II, or III of a standard brand of portland cement. Different types of cement, as prescribed above, may be used in the same structure, but all cement used in any one monolithic placement shall be of the same type and brand. Only one brand of each type will be permitted in any one structure. The cement may be either in bulk or in bags.

The coarse aggregate may be gravel, crushed stone, blast furnace slag, or combinations thereof.

The fine aggregate shall consist of natural sand, a combination of natural sand and manufactured sand, or a combination of natural sand and mineral filler or natural sand, manufactured sand and mineral filler.

Mineral filler shall consist of stone dust, clean crushed shell, crushed sand, or other approved inert material.

II. Concrete Design

A. General

In order to design and control a concrete mixture properly, it is essential to understand the design completely in all of its details. To design a mix mechanically or by a formula is not sufficient. The following explanation is not only the step-by-step procedure of absolute volume design, but the reason for each step is emphasized. It must be born in mind that a complete understanding of each of the factors involved cannot be obtained by a study of one factor alone. In order to understand one, it is necessary to understand all.

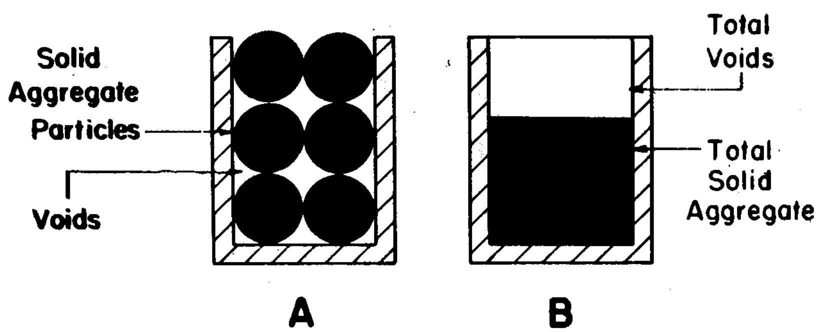
B. Definition of Terms

In order to proceed with the explanation of absolute volume design, it is essential that certain terms be defined clearly.

It is impossible to define all of the terms which may be unfamiliar to an operator inexperienced in the design of concrete and the control of a pouring job, but the following have been selected either because they appear to be most liable to misunderstanding or because they require detailed explanation.

1. Absolute Volume

The terms "absolute volume" and "solid volume" are synonomous and are used interchangeably. The absolute volume of a given amount of material is the total volume of the solid portions of the material. The word "solid" as here used does not necessarily imply "rigid." It merely signifies the absence of air spaces or voids. Water contains no voids; therefore, the volume of a given amount of water is the solid volume of the water. In order to visualize more clearly the solid volume of a material which contains voids, assume a measure of given volume which is filled with loose aggregate. (Figure I - Part A.)



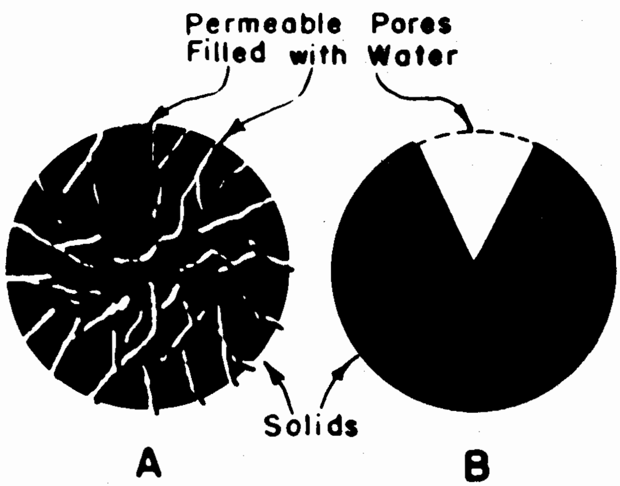
LOOSE VOLUME AND ABSOLUTE VOLUME

FIG. I

Part of the total volume of the measure is occupied by solid aggregate particles, and the remainder of the total volume is occupied by air spaces or voids. Now, assume the aggregate to be converted into a liquid state. The particles will flow together and form a solid mass as in Figure I - Part B, the volume of which is equal to the total volume of all the solid aggregate particles in Figure I - Part A. When the aggregate particles in Figure I - Part A are in a saturated, surface-dry condition, as they are in concrete, the absolute volume of aggregate in Figure I - Part B is the total absolute volume of the impermeable portion of all aggregate particles plus the volume of the absorbed water.

2. <u>Saturated Surface-Dry Condition</u>

An aggregate particle is said to be in a "saturated, surface-dry condition" when its interior permeable pores are completely saturated with water and its surface is dry. In the accompanying figure (Figure II), Part A represents an aggregate particle, the total volume of which is composed of a solid impermeable portion and of permeable capillary pores. In Figure II - Part B, the total volume of the impermeable portion is shown as one mass and the total volume of the permeable pores is shown as one mass. When this particle is immersed for a sufficient length of time, the permeable pores become



filled with water. The aggregate particle will be in this condition when it is a part of a mass of concrete. If the particle had free (surface) moisture at the time the concrete was mixed, the mortar would take this moisture from the surface of the particle. If the particle had absorption (was not completely saturated) at the time the concrete was mixed, the capillary action of the permeable pores would take water from the mortar. Thus, the total absolute volume of the aggregate particle when it is a part of a mass of concrete is the solid volume of the impermeable portion of the particle plus the volume of the water required to fill the permeable pores. Therefore, for the purpose of concrete design, specific gravities are determined on aggregate in a saturated, surface-dry condition, and absolute volumes are calculated on the saturated, surface-dry basis.

3. Absorption

Stockpiled aggregates are seldom, if ever, completely dry, but even though an aggregate contains some absorbed moisture, it may be drier than saturated, surface-dry. Where this is the case, it has the capacity to absorb water. The weight of water which will be absorbed by an aggregate in reaching a saturated, surface-dry condition, when expressed as a percentage of the weight of the dry aggregate (stockpile condition) is known as the "per cent absorption" of that aggregate.

4. <u>Free Moisture</u>

Stockpiled aggregates usually contain surface moisture or moisture in excess of a saturated, surface-dry condition. This excess moisture is known as "free moisture" and, when expressed as a percentage of the weight of the wet aggregate (stockpile condition) is known as the "per cent free moisture."

5. <u>Specific Gravity</u>

Specific gravity is the ratio of the weight of a given absolute volume of a material to the weight of an equal volume of water. (See "Saturated, Surface-dry Specific Gravity.") Thus, water has a specific gravity of 1.0. As an example of specific gravity, consider 1.0 cubic foot of water, which weighs 62.5 pounds, in comparison with a solid cubic foot of stone weighing 125.0 pounds. The volume of the stone is the same as the volume of water, but the weight of the stone is twice that of the water. Therefore, the specific gravity of the stone = 125.0/62.5 = 2.0.

Therefore, it becomes apparent that specific gravity determines the exact relation of weight to volume and vice versa. This is the most fundamental relation in absolute volumes design of concrete. Knowing the specific gravity, the weight may be determined when the volume is known, or the volume determined when the weight is known, as follows:

$$\text{Weight (lb.)} = \text{Volume (cu. ft.)} \times 62.5 \times \text{Specific Gravity}$$

$$\text{Volume (cu. ft.)} = \frac{\text{Weight (lb.)}}{62.5 \times \text{Specific Gravity}}$$

6. <u>Saturated, Surface-Dry Specific Gravity</u>

The "saturated, surface-dry specific gravity" of a material is the ratio of the weight of a given absolute volume of the material in a saturated, surface-dry condition to the weight of an equal volume of water. (See "Specific Gravity.") Saturated, surface-dry specific gravity is the only type of specific gravity (except for cement) used in concrete design. Therefore, for convenience, the words "saturated, surface-dry" are frequently omitted with the understanding that the terms "specific gravity" and "saturated, surface-dry specific gravity" are synonomous.

7. <u>Unit Weight</u>

The unit weight of a material is the weight (pounds) of 1.0 cubic foot of the material in a <u>saturated, surface-dry, and loose condition</u>. The unit weight of an aggregate is not to be confused with the weight of a cubic foot of that aggregate containing free moisture or absorption. When the aggregate is not saturated and surface-dry, the proper correction must be applied before the true unit weight is obtained.

8. <u>Voids (Per Cent)</u>

The air spaces between loose particles of aggregate or cement are known as "voids." The volume of voids signifies that portion of the total volume of loose aggregate which is occupied by the air spaces between the solid aggregate particles. When this volume is expressed as a percentage of the total volume of loose aggregate, it is known as "per cent voids." The "per cent voids" is always the complement of the "per cent solids." (See "Solids.")

9. <u>Solids (Per Cent)</u>

Concrete is designed on the basis of absolute, or solid volume. Aggregates and cement, however, are not solid masses but are composed of separate particles. Thus, while aggregates and cement are proportioned on the basis of solid volumes, they are actually handled in a loose condition. A given volume of cement of aggregate in a loose condition is composed of two separate and distinct volumes, "solids" and "voids." The term "solids" signifies that portion of the total volume which is occupied by solid particles in a saturated, surface-dry condition. When the volume of solids is expressed as a percentage of the total volume of loose cement or aggregate, it is known as "per cent solids." It is obtained by dividing the unit weight of the material by 62.5 (weight of 1.0 cubic foot of water) times the specific gravity of the material, and multiplying the quotient by 100. The "per cent solids" is always the complement of the "per cent voids." (See "Voids.")

10. <u>Design Factors</u>

The water-cement ratio, the coarse aggregate factor, the sand factor, and the cement factor are known as"design factors."

11. <u>Water-Cement Ratio</u>

Water-cement ratio is the number of gallons of mixing water used with one sack of cement. It is frequently referred to as "gallons of water per sack of cement" and might also be termed the "water factor." The symbol "W/C" is used to signify the water-cement ratio.

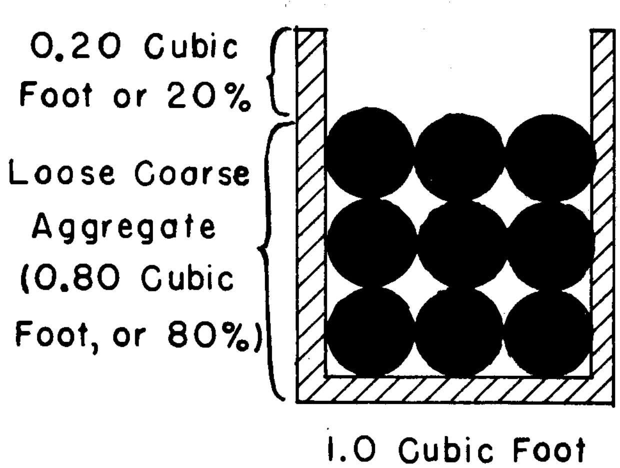
12. <u>Coarse Aggregate Factor</u>

Coarse aggregate factor is the loose volume of coarse aggregate in a unit volume of concrete.

Expressed in another way, the coarse aggregate factor is the percent of any given volume of concrete which is occupied by the loose volume of the coarse aggregate. The symbol "CAF" is used to signify the coarse aggregate factor.

Explanation: Assume that we are making 1.0 cubic foot of concrete with a coarse aggregate factor of 0.80. Without the sand, cement, and water, the coarse aggregate, including the voids, would occupy 0.8 cubic foot, or 80% of the total volume of concrete, leaving 0.2 cubic foot, or 20% of the volume as unoccupied space. Concrete is composed of coarse aggregate and mortar.

Assume a mortar sufficiently fluid so that, when poured into the measure (as illustrated in the accompanying figure (Figure III - A), it will completely fill all the voids in the coarse aggregate. When the measure is completely filled with this mortar, the voids in the coarse aggregate will be completely filled and there will be 0.2 cubic foot additional mortar. This additional mortar is called "Excess Mortar," meaning mortar in excess of the amount required to fill the coarse aggregate voids. In this case, we have 20% excess mortar when the value is expressed as a percentage of the total volume of concrete.

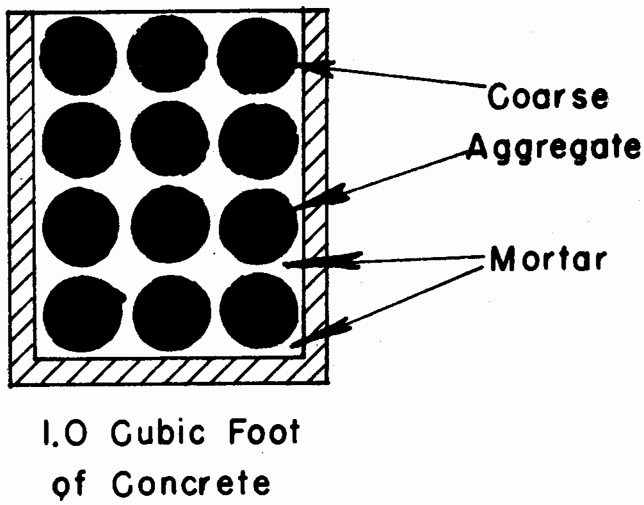


A

COARSE AGGREGATE FACTOR of 0.80

FIG. III

Ordinary concrete mortar is not sufficiently fluid to flow into all the coarse aggregate voids; so let us take the coarse aggregate in the preceding figure and mix it in a normal manner with the same amount of ordinary concrete mortar. The accompanying figure (Figure III - B) represents the concrete which is obtained. This concrete, as in the preceding figure, has a coarse aggregate factor of 0.80 or 80% and excess mortar of 0.20, or 20%. The excess mortar is now distributed throughout the entire volume of concrete, but is, nevertheless, still an excess over and above enough to fill the voids in the loose coarse aggregate.



B

COARSE AGGREGATE FACTOR of 0.80

FIG. III

It is now apparent that the coarse aggregate factor determines the loose volume of coarse aggregate in any given volume of concrete, but this is not all the information available. If we know the per cent solids (or per cent voids) in the coarse aggregate, we can immediately determine the absolute volume of coarse aggregate to be used in any given volume of concrete designed with any given coarse aggregate factor. The absolute volume of concrete multiplied by the coarse aggregate factor equals the loose volume of the coarse aggregate. The loose volume of the coarse aggregate multiplied by the per cent solids in the loose aggregate equals the absolute volume of the coarse aggregate.

From the foregoing explanation, it may be seen that the proportion of coarse aggregate to mortar may be varied by varying the coarse aggregate factor. By increasing the coarse aggregate factor, the absolute volume of coarse aggregate is increased and the absolute volume of mortar is decreased proportionately and vice versa.

Effect upon mix: As the mortar not only fills the voids in the coarse aggregate, but separates the coarse aggregate particles, it is obvious that some excess mortar is always required in order to produce workable concrete. Experience has shown that a minimum of 15% excess mortar (coarse aggregate factor of 0.85) is required to produce paving concrete which is workable and will not produce honeycomb, but ordinarily the best results are obtained with a coarse aggregate factor of from 0.80 to 0.83. Specifications limit the coarse aggregate factor to a maximum of 0.85, but do not require a minimum.

Concrete without sufficient excess mortar to make it workable is said to be "undersanded." Such a mix is harsh and difficult to place and finish properly without producing undesirable honeycomb. The opposite extreme of an undersanded mix is an "oversanded" mix. An oversanded mix has too low a coarse aggregate factor, or more than sufficient excess mortar. It requires much more paste to lubricate a given amount of sand than to lubricate the same amount of coarse aggregate. Thus, if the coarse aggregate factor be lowered excessively, one of two unfortunate conditions will result:

a. If the net amount of paste with a constant water-cement ratio is kept constant, the mix will be dried up and become unworkable.

b. If the water-cement ratio is kept constant and the net amount of mixing water is increased to provide workability, the cement factor is increased and the cost of the concrete increases.

In studying the effect of the coarse aggregate factor upon the workability of the mix, it is also necessary to consider the effect of the voidage content of the coarse aggregate. It has been seen that the absolute volume of coarse aggregate per unit volume of concrete is a function of both the coarse aggregate factor and the per cent solids (or voids) in the coarse aggregate. As the maximum coarse aggregate factor which may be successfully employed is practically constant with a given coarse aggregate irrespective of the voidage content, it is obvious that low voids (high per cent solids) are desirable.

The coarse aggregate factor or the voidage content of the coarse aggregate does not affect the strength of the concrete provided the water-cement ratio remains constant and good workability be maintained.

13. Sand Factor

Sand factor is the loose volume of fine aggregate (sand) in a unit volume of mortar. Expressed in another way, the sand factor is the per cent of any given volume of mortar which is occupied by the loose volume of the fine aggregate. The symbol "SF" is used to signify the sand factor.

Explanation: The sand factor bears precisely the same relation to mortar as does the coarse aggregate factor to concrete. (See "Coarse Aggregate Factor.") Thus, it becomes unnecessary to enter into a detailed explanation of the functioning of the sand factor except to define an additional term which is used frequently. As the paste not only fills the voids in the sand but separates the sand particles, it is obvious that some additional paste is required. This additional paste is called "excess paste," meaning paste in excess of the amount required to fill the sand voids.

It is apparent that the sand factor determines the loose volume of sand in any given volume of concrete, but this is not all the information available. If we know the per cent solids (or per cent voids) in the fine aggregate, we can immediately determine the absolute volume of fine aggregate to be used in any given volume of mortar designed with any sand factor. The absolute volume of mortar multiplied by the sand factor equals the loose volume of the fine aggregate. The loose volume of the fine aggregate multiplied by the per cent solids in the loose aggregate equals the absolute volume of the fine aggregate.

From the foregoing explanation it may be seen that the proportion of fine aggregate to paste may be varied by varying the sand factor. By increasing the sand factor, the absolute volume of fine aggregate is increased and the absolute volume of paste is decreased proportionately and vice versa.

Effect upon mix: Mortar without sufficient excess paste (too high a sand factor) is dry and the concrete produced with such a mortar is difficult to place and finish properly without producing undesirable honeycomb. Mortar with too low a sand factor is too wet and may not be sufficiently plastic and cohesive to secure the desired consistency of concrete. In a mix which is too wet, the constituent ingredients may segregate when placed on the grade and the excessive amount of water may cause undesirable bleeding subsequent to finishing operations. Specifications do not limit the sand factor.

14. <u>Cement Factor</u>

Cement factor is the number of sacks of cement used to produce one cubic yard of concrete. The symbol "CF" is used to signify the cement factor. The cement factor is equal to 27/yield or 27/absolute volume of concrete produced by one sack of cement.

15. <u>Paste</u>

Paste is an intimate mixture of cement and water. With given aggregate, the proportion of water and cement determines the strength of the concrete, and as paste is the lubricant of the mortar, the consistency of the paste determines the consistency or workability of the mortar.

16. <u>Mortar</u>

Mortar is an intimate mixture of cement, water and fine aggregate. With a given coarse aggregate, the quality of the mortar controls both the strength and workability of the concrete.

17. <u>Excess Paste</u>

Excess paste is the absolute volume of paste in excess of the amount required to fill the voids in the fine aggregate. If 0.85 cubic foot of fine aggregate in a loose condition is used to produce 1.0 cubic foot of mortar, then the excess paste = 1.00 - 0.85 = 0.15 cubic foot, or 15%. Hence, the excess paste is always the complement of the sand factor when both are expressed in percentages.

18. Excess Mortar

Excess mortar is the absolute volume of mortar in excess of the amount required to fill the voids in the coarse aggregate. If 0.80 cubic foot of coarse aggregate in a loose condition is used to produce 1.00 cubic foot of concrete, then the excess mortar = 1.00 - 0.80 = 0.20 cubic foot, or 20%. Hence, the excess mortar is always the complement of the coarse aggregate factor when both are expressed as percentages.

C. Mix Design

Absolute Volume design of concrete may logically be divided into two steps:

First, calculate all absolute volumes of each of the four ingredients, using pre-determined design factors of:

1. Water-Cement Ratio (Selected by Designer)
2. Coarse Aggregate Factor (Selected by Designer)
3. Sand Factor (Calculated)
4. Cement Factor (Selected by Designer)
5. Per Cent solids or voids in coarse and fine aggregate (Calculated)

Second, conversion of the designed absolute volumes to saturated surface dry weights. These weights must then be corrected for free moisture or absorption in the aggregate.

1. Design Constants

For the sake of simplicity, certain constant values are used in designing a concrete batch. These design constants are:

1.	Weight of one sack of cement (1 cu. ft. loose)	=	94 lbs.
2.	Weight of one cu. ft. of water	=	62.5 "
3.	Weight of one gallon of water	=	8.33 "
4.	Sp. gravity of Cement	=	3.10
5.	Sp. gravity of Water	=	1.00

2. Design Factors

The "Design Factors" are four in number and each factor is peculiar to one of the four ingredients of concrete. Although each factor is an independent item, the functions of all of them are so interrelated that a change of any magnitude in one factor will cause a change in one or more of the others.

a. Cement Factor

In structural concrete, the specifications denote that concrete shall be designed, using five sacks of cement per cubic yard of concrete.

Thus, the cement factor is specified at 5.0 sks/c.y. Since there are 27 cu. ft. in a cubic yard, it follows that for each sack of cement, we propose to make 5.400 cu. ft. of concrete:

$\therefore$ Cement Factor = 5.0 sk/c.y. (Specified)

Yield = 27/5 = 5.400 C.F./sk

b. Water Factor

This item is generally chosen by the designer. His choice is usually based on experience, with certain broad limitations imposed by the specifications. Item 421 of the Standard Specifications setsout that the maximum water-cement ratio for Class "A" concrete for structures is 7.0 gal./sack. This, then, is the only limitation placed on the designer. For the purpose of this example, let us assume that a Water Factor of 6.5 gal./sk cement is selected.

$\therefore$ Water Factor = 6.5 gal/sk

c. Coarse Aggregate Factor

Item 421.8 sets definite limitations on the maximum allowable Coarse Aggregate Factor. According to the per cent voids in the Coarse Aggregate, the maximum coarse aggregate factor shall be 0.82 of 0.85. For the purposes of this example, let us choose: CAF = 0.80.

d. Fine Aggregate Factor

Since we have already assumed values for the other three values, it is not necessary to assign values for the fine aggregate factor. This factor can be calculated after the design has been completed.

3. Aggregate Characteristics

The physical properties or individual characteristics of the aggregate to be used in the concrete may be determined by various tests. For the purposes of this design, the following test results are assumed:

a. Fine Aggregate

S.S.D. Specific Gravity	=	2.65	
Unit Weight (loose)	=	101.8	lbs/cu. ft.
Per Cent Voids	=	38.6	
Per Cent Solids	=	61.4	

b. Coarse Aggregate

S.S.D. Specific Gravity	=	2.61	
Unit Weight (loose)	=	98.8	lbs/cu. ft.
Per Cent Voids	=	39.4	
Per Cent Voids	=	60.6	

4. Design of a One-Sack Batch

a. Coarse Aggregate

Abs. Vol. CA = loose vol. CA x % solids CA

Loose Vol. CA = yield x CAF

= 5.400 x 0.80

Loose Vol. CA = 4.320 cu. ft.

Abs. vol. CA = 4.320 x .606 = 2.618 cu. ft.

b. Mortar

Abs. vol. mortar = abs. vol. concrete (yield) - abs. vol. CA

= 5.400 - 2.618

= 2.782 cu. ft.

c. Water

Abs. vol. water = water factor ÷ no. gals/cu.ft.

= 6.5/7.5 = 0.867 cu. ft.

d. Cement

$$\text{Abs. vol. cement} = \frac{\text{Unit weight (loose)}}{\text{Unit weight (solid)}}$$

Unit weight loose (1 cu. ft.) = 94 lbs.

Unit weight solid (1 cu. ft.) = Sp. Gr. x 62.5

= 3.10 x 62.5

= 193.75 lbs.

Abs. vol. cement (1 sk.) = 94/193.75 = 0.485 cu. ft.

e. <u>Paste</u>

Abs. vol. paste = abs. vol. water and abs. vol. cement

= 0.867 + 0.485

= 1.352 cu. ft.

f. <u>Fine Aggregate</u>

Abs. vol. FA = abs. vol. water - abs. vol. paste

= 2.782 - 1.352

Abs. vol. FA = <u>1.430</u>

g. <u>Yield</u> = cement and water + FA + CA = 5.400 cu. ft.

h. Fine Aggregate Factor

In the sample design, the FAF was unknown. It is now necessary to calculate the unknown FAF to see if it falls in the proper limits. By definition, the FAF is actually the per cent of any given volume of mortar that is occupied by the loose volume of the fine aggregate

(a) FAF = loose vol. FA/ abs. vol mortar

The loose volume of the FA is equal to the Abs. vol FA ÷ the % solids

(b) Loose vol. FA = abs. vol. FA/% solids

By substituting formula (b) in (a) we find:

FAF = abs. vol. FA/% solids FA x abs. vol. mortar

= 1.430/.606 x 2.782

= 0.837 use .84

The FAF is 0.84 which means that in one cu. ft. of mortar, 0.84 of that cu. ft. is FA, loose measurement. Therefore, the remaining .16 of the cu. ft. will be composed of cement and water - or "excess paste" - meaning paste in excess of that required to fill the voids in the FA. Experience has shown that any good batch design requires a minimum of 0.15 excess paste for lubrication. This design meets that minimum.

5. Calculation of Saturated Surface-Dry Weights

The calculation for the S.S.D. Weights are made for a one-sack batch. By definition, (see Specific Gravity).

Weight = Vol. x 62.5 x Sp. Gr.

Therefore:

Cement - 1 sack	=	94 lbs.
Water - 0.867 x 62.5 x 1.00	=	54.2 lbs(or 6.5 gals/sk)
FA 1.430 x 62.5 x 2.65	=	236.8 lbs.
CA 2.618 x 62.5 x 2.61	=	427.1 lbs.

6. Correction of Weights for Excess Moisture or Absorption

a. Correction for Excess Moisture

Stockpiled aggregates usually contain free moisture, or moisture over and above a saturated surface-dry condition. The relation of weight to absolute volume depends upon the specific gravity, and specific gravities are determined on aggregates in a saturated, surface-dry condition. Therefore, it is important that we be able to compensate stockpile aggregate weights for the difference between a saturated surface-dry condition, and the actual free moisture content of the aggregates.

The per cent of free moisture in a wet sample is the weight of the free moisture divided by the weight of the wet sample. Thus, it is clear that the free moisture is expressed as a percentage of the wet sample weight and not as a percentage of the saturated surface-dry weight.

Let us assume that the above design is to be used in a five-sack batch. The sand in the stockpile has been tested and found to contain 4% free moisture. The gravel contains 1%. What are the correct weights to use on the bin scales? (Bin weights)

(1) For a 5-sack batch - SSD weights are:

Cement	=	94 lbs x 5	=	470 lbs (5 sacks)
Water	=	54.2 lbs x 5	=	271.0 lbs (32.5 gals)
FA	=	236.8 lbs x 5	=	1184.0 lbs.
CA	=	427.1 lbs x 5	=	2135.5 lbs.

(2) Correction for Free Moisture:

As pointed out above, the per cent free moisture in a wet sample is the weight of the free moisture divided by the weight of the wet sample

.•. Wt. free moisture = 4% of wt. sample

Wt. SSD sand = 96% of wt. sample

and Wt. SSD sand = 0.96 (wt. of wet sample)

Wt. of wet sample = Wt. SSD sand/0.96

= 1184.0 lbs/0.96

= 1233.3 lbs. wt.

In order to weigh out 11.84.0 lbs. of SSD sand, it is necessary to actually weigh out 1233.3 lbs. of the wt. sand - of which:

96% is SSD sand (0.96 x 1233.3 = 1184)

4% is free moisture (0.04 x 1233.3 = 49.3)

Gravel is handled the same way as sand

Wt. of wt. sample = 2135.5/0.99

= 2157.1 lbs.

99% is SSD gravel (0.99 x 2157.1 = 2135.5)

1% is free moisture (0.01 x 2157.1 = 27.6 lbs.)

It is necessary to go one step further and correct the designed weight for water in order to take into account the free moisture present in both the sand and the gravel:

Sand = -49.3 lbs.

Gravel = -21.6 lbs.

Total = +70.9 lbs.

Bin Wt. = Design wt. + net correction

= 271.0 lbs. - 70.9 lbs.

= 200.1 lbs.

The final bin weights for the five-sack batch are:

Cement	-	470 lbs.
Water	-	200.1 lbs. (corrected for free moisture)
FA	-	1233.3 lbs. (corrected for free moisture)
CA	-	2157.1 lbs. (corrected for free moisture)

b. Correction for Absorption

In the case of stockpiled aggregate that is dry, then moisture will be absorbed by the material and must be compensated for.

The per cent of absorption in a dry sample is the weight of water which is absorbed divided by the weight of the dry sample. Thus, it is evident that the absorption is expressed as a percentage of the dry sample weight and not as a percentage of the saturated surface-dry sample weight.

Let us assume that the sample design above is to be used in a five-sack batch. The sand in the stockpile is tested and found to have free moisture of 4%. The gravel is tested and found to have absorption of 2%.

(1) <u>For 5-sack batch</u> - see F,1, above for SSD wts.

(2) <u>Correction for free moisture</u> - The correction for free moisture shall be the same as outlined above:

Wt. of wet sample	= Wt. of SSD sand/0.96
	= 1184.0/0.96
	= 1233.3 lbs. wet sand
Wt. SSD sand	= 1184.0 lbs.
Wt. free water	= 1233.3 - 1184 = 49.3 lbs.

(3) Correction for Absorption:

As pointed out above, the per cent absorption is the wt. of water absorbed divided by the dry wt. of the sample.

SSD gravel = dry gravel increased by % absorption

= dry gravel x 1.02 (100% + 2%)

Dry gravel = SSD gravel/1.02

= 2157.1/1.02

= 2114.8 lbs.

Wt. SSD gravel = 2157.1 lbs.

Wt. water absorbed = 2157.1-2114.8 = 42.3 lbs.

It is necessary to correct designed weight of water for % free moisture or % absorption.

Net Correction = Wt. water absorbed - wt. free water

= 42.3 - 49.3

= -7.0 lbs.

Bin Wt. = Design wt. + net correction

= 271.0 lbs. - 7.0 lbs.

= 264.0 lbs.

The final bin weights for the five-sack batch are:

Cement - 470 lbs.
Water - 264 lbs.(corrected for free moisture and absorption)
FA - 1233.3 lbs. (corrected for free moisture)
CA - 2114.8 lbs. (corrected for absorption)

III. Materials

A. Specification Requirements

1. Sand

Item 421.2(4) gives the exact specification requirements for fine aggregate to be used in concrete for structures. The major requirements are:

a. Fine aggregate shall consist of natural sand, a combination of natural sand and manufactured sand with or without a mineral filler.

b. All fine aggregate shall be free from all frozen or foreign material.

c. All fine aggregate shall be free from an excess of salt, alkali, or vegetable matter.

d. All fine aggregates shall not contain more than 0.5 per cent by weight of clay lumps.

e. When subjected to the color test for organic impurities (ASTM Designation C-40), the fine aggregate shall not show a color darker than the standard.

f. When the fine aggregate is mixed with high early strength portland cement in the proportion 1:3, the average strength per sq. in. of not less than three standard mortar briquettes shall be equal to or greater than the strength of Ottowa sand mortar briquettes of the same proportions and consistency, when tested at the age of three days.

g. When tested by approved methods, the fine aggregate shall conform to the grading requirements shown below:

Sieve Size	% Retained
3/8	0
No. 4	0 to 5
No. 8	0 to 20
No. 16	15 to 20
No. 30	40 to 75
No. 50	70 to 90
No. 100	90 to 100

h. The fineness modulus of the sand shall be:

Class Concrete	F.M.
A, C, & E,	Min 2.20, max. 2.90
F & G	Min 2.40, max. 2.90

The fineness modulus of the fine aggregate shall be determined by adding the percentages by weight retained on the following screens and dividing by 100.

Nos. 4, 8, 16, 30, 50 and 100.

2. Gravel

Item 421.2(3) gives the exact specification requirements for coarse aggregate to be used in concrete for structures. The major requirements are:

a. Gravel or crushed stone shall have a wear of not more than 40 per cent when tested according to AASHO Method T-96.

b. Coarse aggregate shall be free from an excess of salt, alkali, vegetable matter, or other objectionable material, either free or as an adherent coating on the aggregate.

c. Coarse aggregate shall not contain more than 0.25 per cent by weight of clay lumps, nor more than 1.0 per cent by weight of shale, nor more than 5.0 per cent by weight of laminated or soft particles.

d. Maximum size of aggregate shall be governed by the type of structure in which the concrete is to be used as shown below.

e. Coarse aggregate shall conform to grading requirements as shown below.

Aggregate Grade No.	Maximum Size	Per Cent Retained							
		3"	2½"	2"	1½"	1"	3/4"	½"	No. 4
1	2½"	0	0 to 5	0 to 20	15 to 20		60 to 80		95 to 100
2	1½"			0	0 to 5		20 to 70		95 to 100
3	1"				0	0 to 5	15 to 45	50 to 75	95 to 100

f. Unless otherwise specified on the plans, the loss by decantation shall not exceed 1%.

3. <u>Cement</u>

Item 421.2(1) gives the exact specification requirements for cement to be used in concrete for structures. Only those requirements which are checked in the field will be listed herein. They are:

a. Different types of cement may be used in the same structure, but all cement used in any one monolithic placement shall be of the same type and brand.

b. Only one brand of each type will be permitted in any one structure, except when otherwise authorized by the Engineer.

c. Cement may be delivered in bulk where adequate bin storage, batching and weighing equipment is provided.

d. All other cement shall be delivered in bags on which shall be marked plainly the name of the manufacturer and the type of cement.

e. In general, bags shall contain 94 lbs. net and shall be in good condition at the time of delivery.

f. Bags varying more than five per cent from the specified weight may be rejected, and if the average weight of bags in a shipment, as shown by weighing 50 bags at random, is less than 94 lbs., the entire shipment may be rejected.

g. All cement shall be properly protected against dampness and no cement will be accepted which has become caked.

h. All cement shall be sampled and tested in accordance with THD requirements as listed in Test Method Tex-300-D Manual of Testing procedures.

i. The Engineer shall be notified upon receipt of shipments of cement in order that he may witness the opening of the car. Failure to comply shall be grounds for rejection of the shipment.

4. <u>Mixing Water</u>

Water from doubtful sources shall not be used until tested and approved. The Contractor shall not take water for use in concrete from shallow, muddy, or marshy sources. Item 421.2(2) gives the exact specification requirements.

5. <u>Admixtures</u>

There are several different types of admixtures that may be added to concrete batches to change its properties. Item 437, "Concrete Admixtures," is the governing specification in this case.

a. Air Entrainment Admixtures

An air entrainment admixture is a material which, when added to a concrete mix in the quantity recommended by the manufacturer, will entrain uniformly dispersed microscopic air. Item 437.4 gives the exact requirements governing the use of air entraining agents. The major points are:

(1) The air entraining admixture when used in the correct quantities to produce three to six per cent entrained air, shall produce seven-day compressive strengths not less than 85 per cent of the seven-day compressive strengths of the non-air-entrained concrete.

(2) The tests for compressive strength shall be standard 6" diameter x 12" length cylinders, made and cured in accordance with ASTM Designation C-192 (Test Method Tex-418-A). A minimum of three cylinders of reference concrete and three cylinders of the test concrete will be tested at the age of seven days. Equal slump will be maintained within one-half inch for the test and reference concrete.

The manufacturer shall furnish the Department Laboratory, Camp Hubbard, Austin, Texas, with three copies of test reports from a recognized laboratory, showing that the admixture meets all requirements of Item 437. A list of approved admixtures is put out in the form of a D-9 Circular Letter.

b. Cement Dispersing Admixtures

A cement dispersing admixture is defined as a material which, when added to a concrete mix in the quantity recommended by the manufacturer, will change the physical characteristics and properties of the concrete as outlined in Item 437.3 of the Standard Specifications.

The general terms applied to proprietary compounds such as "retarders," "retarding densifiers," "water reducing agents," "wetting agents,", etc., will be classed as cement dispersing admixtures. These admixtures may, or may not, entrain air. They will be classed as for use by the Department only if the requirements outlined in Item 437.3 are met.

As in the case of air entraining admixtures, a list of approved agents is put out in the form of a D-9 Circular Letter.

6. <u>Lightweight Aggregates</u>

Item 423, page 487, of the Standard Specifications is the governing requirement concerning the use of lightweight concrete. According to Item 423.3, lightweight aggregate shall consist of burned clay or burned shale, having strong durable particles and conforming to the requirements of Standard Specifications for Lightweight Aggregates for Structural Concrete, ASTM Designation C-330. Fine and Coarse aggregates shall conform to the following grading requirements. (Special Provisions to Item 423-423-002)

	Per Cent Retained on Sieve				
	1"	3/4"	3/8"	4	8
Coarse Aggregate	0	0-10	45-80	90-100	95-100

B. Stockpiling and Handling

1. Aggregates

Aggregate stockpiles should be built up in layers. Prior to beginning the formation of an aggregate stockpile, the area that the pile will cover should be cleaned of all extraneous matter and left in a smooth, uniform condition. The stockpile should be located in such a way that it will have good natural drainage.

Stockpiles should be built up carefully, and material should be placed in successive horizontal layers not to exceed two to three inches in thickness. All aggregates must be handled and stored in such manner as to prevent segregation and contamination by foreign substances. Care should be taken to avoid "coning" of the pile, because segregation is certain to result due to the fact that the larger sizes roll down the outside of the pile, leaving the finer particles to the inside.

When stockpiles are built, the material should not be allowed to drop free for any considerable distance. If the material is allowed a long free fall, the larger pieces may fracture, and the wind may blow away the finer particles. To avoid these objectionable features, buckets should be opened only a slight distance above the pile, or in the case of a conveyor loader, a "chimney" should be used.

Boards, burlap, etc., used for patching holes in aggregate cars will frequently get mixed with the aggregate. These, of course, should be removed during the unloading and stockpiling operation. Screens or "grizzlies" with maximum six-inch square opening should be placed on top of the aggregate lines to catch foreign material that was undetected during previous operations. These screens should be cleaned regularly.

Operation of any construction equipment on the piles should be avoided when possible. Tracked vehicles tend to break up the larger sizes of aggregate, and both tires and tracks will carry dirt onto the pile if care is not exercised.

Space should be left between the piles so that there will not be any contamination of one size aggregate by another. In areas where available space is limited, adequate bulkheads should be placed between the piles. The inspector should observe the filling of the batch plant lines to insure that there is no contamination of one size by another due to spillage. This must be watched very carefully when three lines are being used. In this case, aggregate destined for the center compartment must be carried over one of the end compartments during filling operations.

When stockpiles are depleted, the Contractor should be warned to leave the bottom thin layer of material in place to avoid including any foreign material or dirt in the aggregate.

2. <u>Cement</u>

Cement must be stored in a weathertight, dry storage room. On small structural concrete jobs, using one-site mixing, cement is normally delivered in bags. It is then transported to the jobsite area and stored in a warehouse. The Contractor will then remove as many bags as are needed at the site for each pour. Many times, excess cement will be brought to the mixing site, and the Contractor will want to leave the bags at the mixer and cover them with a tarp for the night and then use them on the next pour. This should not be permitted, as the cement will absorb moisture from the air, even though it is covered.

On projects where transit mix concrete is used, the cement is normally delivered in bulk and stored in large silos. These silos should be checked regularly to see that they are weathertight and free from foreign material or old caked cement.

C. Records to Keep

1. Aggregates

An accurate record must be kept of the amounts of the various aggregates received on the project. This record should reflect the following information.

a. Type of aggregate

b. Date received

c. Amount received

d. Producer

In addition, it is necessary to record the disposition of the various aggregates as they are used on the job, or removed from the job by the Contractor. Any material that is wasted or used otherwise by the Contractor must also be accounted for. This record should reflect the following information.

a. Amount used on project

b. Amount tested and Lab. No.

c. Amount wasted

d. Amount remaining on hand of Contractor (Show disposition)

A record must also be kept of the various tests run on the material in the Field Labs. This is in addition to the tests run by the Austin Lab. These tests are:

a. Sieve Analysis

b. Fineness Modulus of Fine Aggregate

c. Sat. Sur. Dry Sp. Gravity

d. Unit Weight

e. Per Cent Solids and Voids

f. Decantation Test for Coarse Aggregate

g. Other tests as required

2. Cement

As in the case of the aggregates, an accurate record must be kept of the amounts of the cement received on the project. This record should reflect the following information:

a. Type and brand of cement

b. Amount received

c. Date received

d. R. R. car seal number

In addition, it is necessary to record the disposition of the various aggregates as they are used on the job by the Contractor. Any material that is wasted or otherwise disposed of by the Contractor must also be accounted for. This record should reflect the following information:

a. Amount used on project

b. Amount tested and Lab. No.

c. Amount wasted

d. Amount retained by Contractor (Show disposition)

Since there is not normally any test run on cement in field labs, no record of tests is required, other than the Austin Lab. No. as indicated above.

3. <u>Admixtures</u>

Records of various concrete admixtures received and used on the project must be kept in the above manner. Since these admixtures are already approved by the Austin Office, no samples are required to be sent for testing. However, records must be kept of the various design tests run in the field.

D. <u>Inspectors' Checklist</u>

1. Check all materials to see that they meet the specification requirements. This is done by submitting a sample to Austin and by running the various tests to be done in the field lab. Approve materials for use.
2. Check proposed location of all stockpiles. See that they are cleaned off and well drained. Inspectors are cautioned about stockpiling aggregate on the proposed roadbed. Any stockpile of aggregate tends to cause a wet, soft spot underneath the pile. This condition would create an unsatisfactory condition in subsequent roadway operations.
3. Check construction of material stockpiles - watch for material segregation. Take corrective action as necessary.

4. From physical tests, make concrete batch design. Several designs should be made, using various water factors.
5. Keep records of material received, material used, and tests, all up to date.

IV. Field Control and Staking of Structures

A. General

The necessary clearing, grubbing and channel excavation should be completed before the construction stakes for any structure are placed. Before any staking is done, a "plans-in-hand" examination of the structure site should be made to compare the topographic features shown, with the existing features on the ground. Any differences should be fully investigated to determine if there is any necessity for a change in the location or design of the structures as planned.

Before starting work on any project, the arrangement of construction stakes should be discussed with the Contractor. All parties concerned, the Inspector, the Engineer, and the Contractor's personnel should have a clear understanding of the proposed arrangement of control stakes. It is advisable to make a written record of this discussion with copies going to all concerned.

B. Definitions and General Staking Terms

The terms used throughout this discussion to describe the stakes used are as follows:

1. Construction Stakes - All stakes of a temporary nature which are placed to locate any unit of the structure by direct measurement.

The staking of any structure involves the placing of two distinct sets of stakes. The first set consists of the construction stakes from which the Contractor makes direct measurements to determine the location and dimensions of the structure on the ground.

The minimum number of construction stakes necessary for the location and construction of any structure is four stakes. These stakes must delineate the two axes of the structure or structure unit and be so located that the Contractor can complete the layout of the excavation limits or forms by direct measurements. The same stakes can be used for both line and grade information. These stakes fulfill the contract requirements of Item 5.7, Construction Stakes, of the Standard Specifications.

Additional stakes, marking portions of the structure, may be set if the Contractor specifically requests more. However, the Contractor must be given to understand that any additional stakes are given as a convenience and the Contractor will be responsible for the accuracy of the work on the additional lines and grades to the extent that these measurements can be verified from information shown on contract plans, and to the degree of accuracy which can be expected through normal and prudent use of the mechanics' tools such as tapes, rules, spirit levels, etc.

2. <u>Reference Stakes</u> - All stakes of a permanent or semi-permanent nature which are used to locate construction stakes or portions of the structure from outside the limits of the construction area.

The second set of stakes consists of reference stakes. These stakes do not ordinarily enter directly into any of the Contractor's operations and are intended to serve as witnesses to the location of the construction stakes for the benefit of the Engineer or Inspector.

Due to varying conditions encountered at structure sites, It is recommended that a study of the site be made to determine the most satisfactory arrangement and location of reference stakes. This arrangement should be such that it will afford simple, rapid and accurate relocation of any construction stake that may need to be replaced during the period of construction.

3. <u>Hub Stakes</u> - All stakes on which tack points are set and elevations read, that are driven flush or below the surface of the ground to maintain their security.

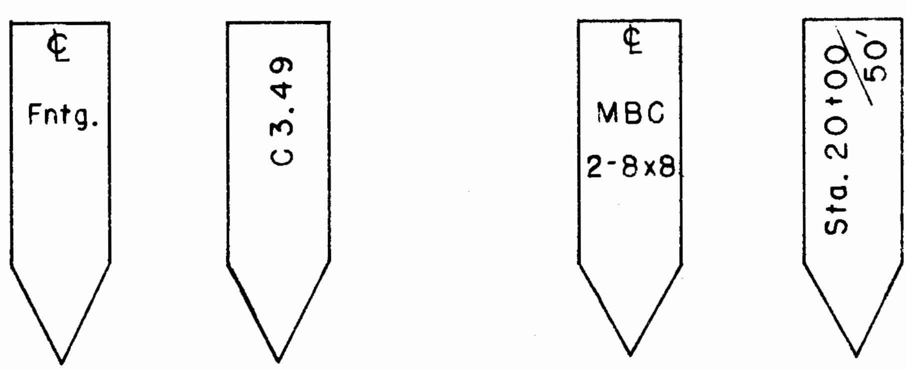
The depth to which hub stakes should be driven should be predetermined, as far as is practicable, and should be uniform for each project. Most modern construction equipment is such that a hub stake must be driven several inches below the surrounding ground surface to remain undisturbed for any appreciable length of time.

4. <u>Guard Stakes</u> - Those stakes which are left projecting above the ground in the vicinity of a hub stake to mark the location of such a hub and identify it.

The primary function of any guard stake is to show the location of a hub stake and identify it. With the fast-moving, bulky, construction equipment now in use, it is impossible to install guards of a character that will serve as a definite physical obstruction to such equipment. It is, therefore, advisable to place the guard stake a sufficient distance from the hub to avoid disturbing the hub if the guard stake is knocked out.

In the past, when survey parties were a more permanent organization, it was customary to instruct the stake drivers in the method of driving hub and guard stakes and establish a uniform arrangement which permitted easy identification and location of the hub and the setting of an instrument over the hub without moving the guard. Such instruction is still in order and the distance of the guard from the hub should be the same in all practicable cases. The guard should always be set in the same direction from the hub with reference to the centerline of the project.

5. <u>Marking Stakes</u> - All stakes, both guard and hub stakes should be marked with the essential information to give proper identification. Construction stakes should be marked on one side with the name of the unit of the structure for which the stake is to be used and, on the other side, with the cut or fill to the plan grade of the structure unit. Reference stakes must show the unit of the structure and the centerline station on one side and the distance to the centerline on the other side. (See Figure IV.)



Construction Stake Reference Stake

FIG. IV

6. <u>Bench Marks</u> - Construction bench marks must be available for use at each structure. The location of these bench marks should be chosen to afford easy and rapid establishment of the structure grade.

On large structures, a complete circuit of bench marks should be established which will furnish convenient means of setting grade elevations for each unit of the structure. The use of shallow-rooted trees which may change position during alternate wet and dry periods, for bench mark locations should be avoided.

C. Culvert Stakes

1. Small Culverts

The staking of any small culvert involves the location of the center of the culvert by such construction stakes along the centerline of the highway that will permit the layout of the transverse axis of the culvert by direct measurement. In addition, this longitudinal axis of the structure must be located in the same manner. These stakes should be referenced by additional stakes outside the limits of construction operations as previously described. (See Figure V.)

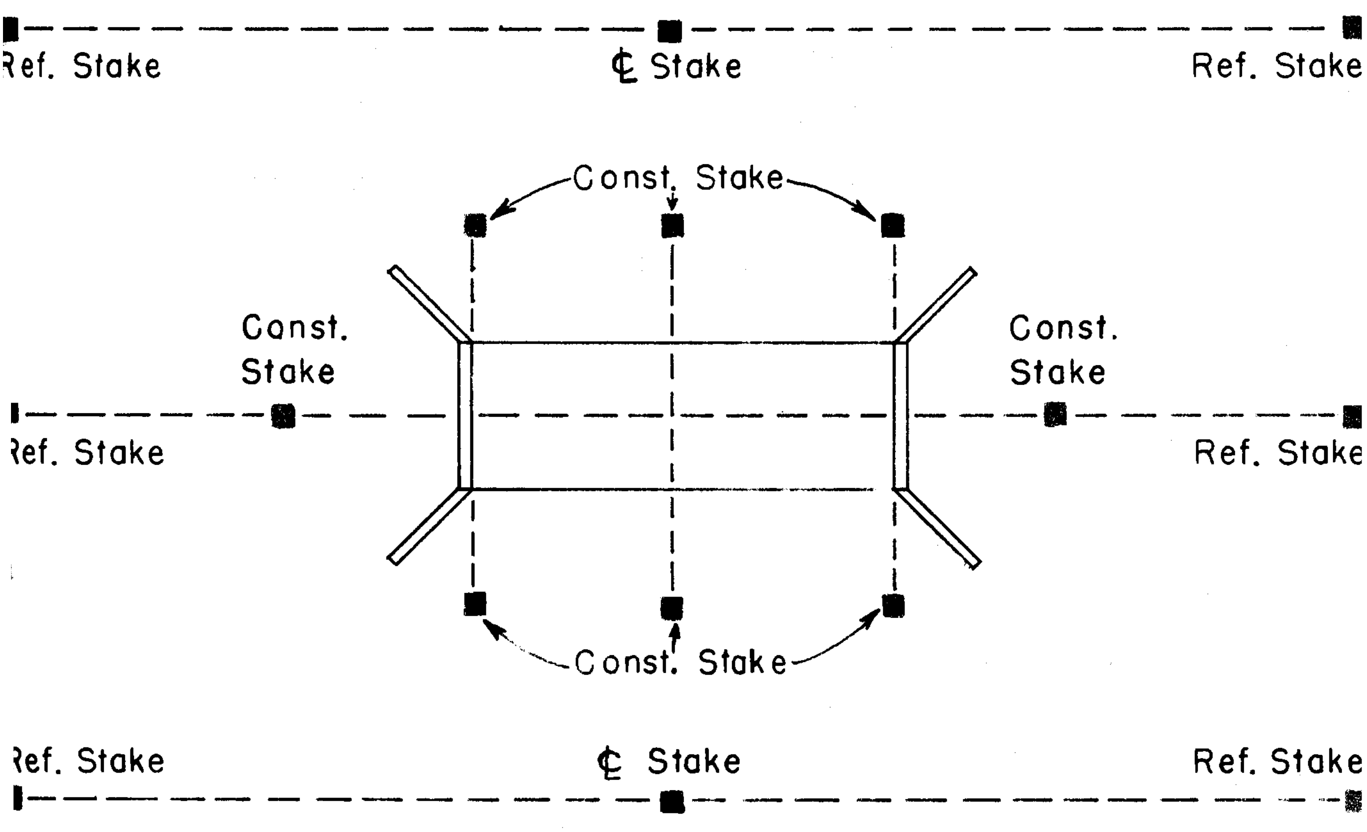


FIG. V

2. Multiple Box Culverts

On large multiple box culverts, the beginning and end walls of the structure should be staked in preference to the axis across the centerline of the highway. The centerline along the highway will be staked as for small culverts. (See Figure VI.)

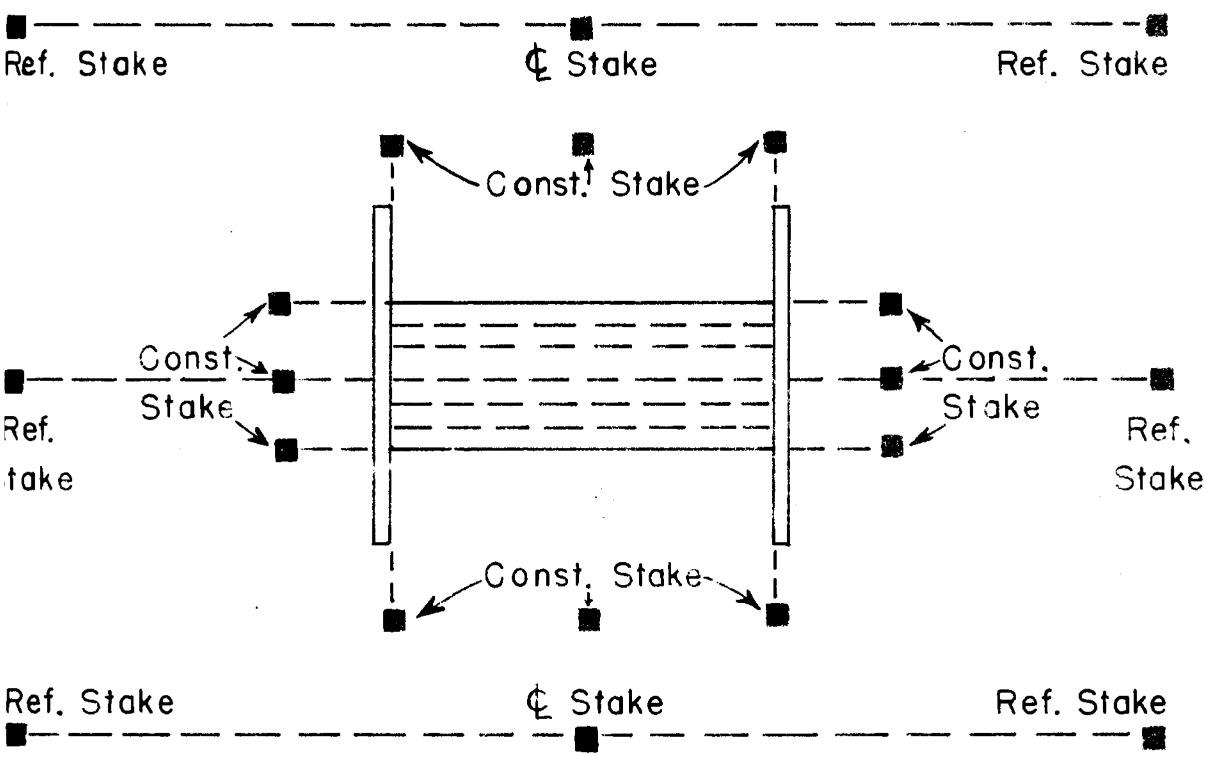


FIG. VI

D. Records to Keep

The necessity for accurate records of the various stakes and grades set should be apparent. The desirability of clearness and conciseness in such records is mandatory. These records may be used by several different men during the course of a project. A hardback field book should be used for the records of stakes set. There is no set form for notes. It is customary to keep the level notes on the left-hand page and record a plan view of the staking layout on the right-hand page. Any logical format may be used so long as the information is recorded clearly and concisely.

E. Inspector's Checklist

1. At beginning of project, have an agreement confirmed in writing, concerning the number and type of stakes to be set.
2. Check plans and determine location, type, and dimensions of structure to be staked.
3. Examine site on ground to determine if any changes from plan proposal is indicated.
4. Set construction and reference stakes required.
5. Make an independent check of each stake set.
6. Record both original work and independent check.
7. Make periodic checks of all stakes set to determine if they have changed position.

V. Structural Concrete Forms

A. Specification Requirements

1. General

Item 420.9(1),Concrete Structures, covers the general requirements for forms. Each inspector should study this item thoroughly and be familiar with every fact. The major requirements are:

a. Forms may be either wooden or metal, as the Contractor elects. Inspectors are cautioned that the use of metal forms by the Contractor requires the same amount of detailed checking as wooden forms - sometimes, more difficulties are encountered.

b. Forms for precast, prestressed members and piling shall be steel. Forms for round columns, exposed to view, shall be steel unless written permission to use other materials is given by the Engineer.

c. It is the general intent that forms shall be in a mortar-tight condition and be strong enough to prevent bulging between supports. In other words, the forms and supporting falsework shall be strong enough to maintain line and grade. This is a critical and important point. The inclusion of this requirement enables the Inspector to require any measures he deems necessary to insure forms of sufficient strength.

d. If forms show signs of bulging or sagging during pouring, the concrete causing this condition shall be removed immediately, if necessary, and the forms reset and braced.

2. Timber Forms

Item 420.9(2) contains the detailed requirements for timber forms. This specification covers not only the placing of forms, but the construction of them as well. No matter how well braced a form might be, if it is not well-constructed, it will fail. The major requirements are:

a. Lumber for forms shall be seasoned properly and be of good quality, free from loose knots, holes, shakes, decay, etc., and other imperfections which would affect the strength. Lumber used for facing or sheathing shall be surfaced on at least one side and two edges and shall be sized to uniform thickness.

b. Timber forms for exposed surfaces which are to receive a Type 1, 2, or 3 finish shall be lined with an approved form lining material, such as masonite, plywood, etc. No lining will be required on any portions of areas inside of culvert barrels, nor on any surface of such dimension that the face form is a single smooth board of a width equal to, or greater than, the surface. Form lining is ignored in checking the strength design of forms.

No form lining will be required for surfaces which are to receive a Type 4 Surface Finish.

c. If desired by Contractor, forms may be constructed of plywood, not less than one-half inch in thickness, with no form lining required. In this case, the supporting joists or studs shall have a clear spacing of not more than twenty times the actual thickness of the plywood. The grain of the face plies shall be laid parallel to the span between studs or joists.

Plywood used for forms for surfaces which remain exposed shall be equal to that specified as "Exterior Type" of the grade "Concrete-Form Exterior" of the United States Department of Commerce, National Bureau of Standards, Commercial Standard, latest edition.

d. Forms or form lumber to be re-used shall be maintained in good condition as to accuracy, shape, strength, rigidity, tightness and smoothness of surface. Forms shall be re-worked between each use. When wood forms are to be re-used, the Inspector should keep in mind that the condition of these forms must be such that the surface produced will be the equivalent of surfaces produced with new lumber. When such forms have developed cracks due to shrinkage, they should be reconstructed in a manner that will eliminate all cracks and irregularities. Patching of holes and splits with pieces of roofing felt or tin or similar materials should not be permitted.

e. Studs and joists shall not be less than two inches by four inches nominal section, and the clear span between them shall not be greater than twenty times the actual thickness of the facing lumber. Studs shall be capped at the top with a plate of not less than two inches by four inches, nominal size. All joints in plates shall be scabbed at least four feet each way.

f. Wales shall be spaced at such intervals as to hold forms securely to the designated lines. All wales shall be scabbed at least four feet on each side of joints to provide continuity. A row of wales shall be placed within six inches of the bottom of each placement.

g. Forms shall be braced rigidly to prevent movement while placing concrete.

h. All face form material shall be fastened to all studs and shall have true horizontal and vertical joints.

i. Molding specified for chamfer strips shall be redwood, cypress or pine of such grade that it will not split when nailed and which can be maintained to a true line without warping.

j. All forms shall be so constructed as to permit removal without damage to concrete. If desired by Contractor, the forms may be given a slight draft to permit ease of removal. The Inspector is cautioned not to permit too great a draft to be given to structure sections on which other portions of the structure are to be erected. Normally, a variation of one-fourth inch in dimension of the section should be sufficient.

k. Metal form ties of an approved type or a satisfactory substitute shall be used to hold forms in place. Such ties shall be of a type as to permit ease of removal of the metal as hereinafter specified. All metal appliances used inside of forms to hold them in correct alignment shall be removed to a depth of at least one-half inch from the surface of the concrete and shall be so constructed that the metal may be removed without undue injury to the surface by chipping or spalling. Burning off of rods, bolts, or ties will not be permitted.

Metal ties shall be held in place by devices attached to wales. Each device shall be capable of developing the strength of the tie, and shall be the adjustable type to allow for lining forms. The use of wire, in lieu of approved metal form ties, is not to be permitted except for minor form areas where the rigid-type metal ties would be impractical. Experience has shown that there are very few areas where form ties cannot be used in place of wires, and the efficiency of ties over the wires in securing straight lines is appreciable.

l. Metal and wooden spreaders which are separate from the forms shall be removed entirely as the concrete is being placed.

m. Wherever practicable, forms shall be erected complete before the reinforcement is placed.

n. For narrow walls and other locations where access to the bottom of the forms is not readily attainable, adequate clean-out openings shall be provided.

o. At the time of placing concrete, the forms shall be clean and free entirely from all chips, dirt, sawdust, and other extraneous material.

p. The facing of all forms shall be lubricated with oil before concrete is placed. In hot weather, both sides of face forms may be required to be treated with oil to prevent warping and to secure tight joints. The oil used for this purpose shall be a clear, light oil which will not discolor or affect the concrete.

q. All forms shall be wetted thoroughly before the concrete is placed therein.

3. <u>Metal Forms</u>

The above requirements listed for timber forms shall apply also to metal forms, insofar as possible, except that no form lining shall be required. In addition, Item 420.9(3) contains some additional requirements regarding the use of metal forms. The major additions are:

a. Metal used for forms shall be of such thickness that the forms will remain true to shape. The minimum thickness of metal used in forms for cylindrical columns or shafts shall be three-sixteenths inch.

b. Forms may be made in sections of such length as will facilitate the placing of concrete and the removal of forms. The fit of joints of sections shall not produce offsets.

c. All bolt and rivet heads on the facing sides shall be countersunk.

d. Clamps, pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete.

e. Metal forms which do not present a smooth surface or line up properly shall not be used.

f. Metal shall be kept free from rust, grease, or other foreign material that will tend to discolor the concrete.

4. Falsework and Form Supports

All falsework shall be designed and constructed so that no settlement or deformation will occur, and so that the necessary rigidity will be provided. Item 420.8 of the Standard Specifications contains the detailed requirements for falsework. Some of the major points are:

a. All timber for wedges shall be hardwood. It is the purpose of this specification to provide wedges at critical points, which will not compress readily under heavy loads, and which may be driven to make adjustments without danger of failure from blows of a hammer. In general construction, there are places for the use of wedges in sections of the construction which may be classed as falsework, which are merely tightening wedges. It is not necessary that these wedges be hardwood. If a wedge is one which controls a portion of the critical lines of the structure and one which may have to be driven tighter for adjustment of these lines, it is considered necessary that hardwood material be used.

Because it is necessary that adequate bearing be maintained at all critical points where wedges are used, all wedges shall be sawed with true surfaces and should be used in pairs. Single wedges should be allowed only where the bearing face of the timber has been mitered to fit the wedge. The use of wedges to compensate for incorrectly cut bearing surfaces will not be permitted.

c. Timber piling may be of any species of wood which will withstand driving satisfactorily and which will adequately support the superimposed load. Piling falsework is considered the most desirable type of falsework for general use. It should be used whenever there is any doubt of the stability of the soil under the span, or its ability to support the anticipated loads without settlement. It is particularly desirable where the surface of the ground has been formed by newly-placed embankments or has been disturbed by excavation.

d. Steel members shall be of adequate strength and of such shape as to be suitable for the purpose intended.

e. Where sills or timber grillages are used to support falsework columns, they shall, unless founded on solid rock, etc., be placed in excavated pits and backfilled to prevent softening of the supporting material.

B. <u>Inspection of Forms</u>

1. <u>General</u>

The correction of errors in form and falsework construction can be most successfully accomplished during the actual period of form construction. It should be the duty of the Inspector to examine the forms during construction and erection, to discover unsatisfactory workmanship. He should be careful, however, not to usurp the authority of the Contractor's superintendent in calling attention to any errors. He should transmit his comments and recommendations in the proper manner.

In general, the better the quality of workmanship on forms, the better the final appearance of the structure. Smooth joints in forms, well-cut and installed chamfer strips, and square-cut timber on timber joints, all make for a minimum of corrective measures on the completed structure and are to the advantage of the Contractor.

To prevent unnecessary delay, the Inspector should be prepared to cover the final inspection of the completed forms in the shortest possible time.

2. Lines, Grades, and Tolerances

Considering the materials ordinarily used for the construction of forms, some tolerance should be permitted in the dimensions of the completed forms. The maximum difference between the actual plan dimensions and the dimensions of finished work should not, however, exceed one-fourth inch. On important or critical items, this tolerance should be reduced to one-eighth inch.

It is both practicable and preferable to set and completely install all chamfer strips before placing concrete. The forms should be set at the final desired alignment before the chamfer grades are set and any allowance for swelling or settlement should be introduced after the chamfer has been placed. This is recommended to insure the return of the form to the desired grade after it is filled and in proper alignment. The one exception to this procedure is bridge caps on piling bents. This will be discussed in the course on bridge inspection.

The layout of any culvert form or footing form should be checked from the original control stakes before any concrete is poured.

The dimensions of any new form should be carefully checked to see that it will conform to the plans in all respects. The thickness of all wall forms should be checked at various points throughout the wall by means of an accurately cut measuring block or by a rule.

3. <u>Bracing and Support</u>

The type and location of braces, form ties, and spreaders should be examined for conformity with the specifications and with the approved form plans.

The size and spacing of shoring in culvert forms should be analyzed for adequacy and all wedges under such forms should be hardwood and double.

The workmanship on all shoring under forms for concrete should be examined and all poorly cut joints, improperly installed wedges, and inadequate braces should be corrected before concrete placing is started.

The forms for all structures which are supported on falsework should be furnished with some type of "tell-tale" device which will indicate the amount of settlement taking place during the loading of the forms. These devices should be such that it will be possible to discover and correct undue settlement before the concrete placing is too far advanced.

Tell-tale devices may be free-hanging chamfer strips nailed to beams or deck locations and extending to contact with stakes driven in the ground on which marks denoting the allowable limits of settlement may be made. They may also be string lines drawn between the supporting caps, which are referenced to definite marks on the sides of the forms.

4. <u>Pier Column and Wall Forms</u>

When inspecting pier, column and wall forms, prior to placing, the Inspector should assure himself that the form construction is adequate for the height of concrete to be placed and the rate of placing to be used. During the erection of these forms, there is always a possibility that the form ties may become loosened by workmen climbing in and out of the forms. The final inspection should include a check of these ties to see that no loose ties exist which will cause unnecessary bulging.

The Inspector should never depend on the use of a carpenter's level for plumbing high vertical forms. On piers, columns and walls, the Contractor should install plumb bob points from which plumb bobs may be suspended on the outside of the forms at definite distances from the concrete lines. These should be checked before placing is started and definite plumbing points marked for use during the placing operation. Instrument control should be maintained at all times on major structure units from offset hubs which will permit accurate checking.

5. <u>Lines and Grades during placing of Concrete</u>

In addition to keeping watch on the tell-tale, previously discussed, the Engineer should have permanent hubs and foresights located on each critical line such as the curb lines of headwalls or bridges, etc. These permanent hubs and foresights control the vertical alignment of the curb forms. After a curb has been filled, the ends and necessary intermediate points should be brought into correct alignment with a transit and the remainder checked with a string line. Following the check for alignment, the top curb chamfers, both inside and out, should be adjusted with an engineer's level and rod, to the final plan elevations. This operation should be accomplished by moving the entire form, either with wedges or jacks as the case may be. These operations should be done as rapidly as possible so that the necessary adjustment may be completed before the concrete has taken its initial set.

C. Inspector's Checklist

1. Check Item 420.9(1) of the Standard Specifications for detailed requirements for concrete forms. Have these details well in mind.

2. Check lumber to be used for forms for seasoning, knots, holes, shakes, etc.

3. Check type of finish required and see if form lining or plywood is being used in proper areas.

4. Check forms for cracks, holes and other irregularities.

5. Check clear span of sheathing between supporting studs or joists.

6. Check size of studs or joists.

7. Check cap at top of studs.

8. Check location of walers.

9. Check falsework and form supports.

   (1) Timber used

   (2) Wedges

   (3) Piling

   (4) Steel members

   (5) Mud sills or grillages

10. General workmanship of forms

    (1) Joists

    (2) Chamfer strips

    (3) Appearance of work

11. Lines, Grades and Dimensions

    (1) Dimensions

    (2) Elevations

    (3) Width of walls, etc.

12. Set tell-tale devices

13. Check devices during pouring

14. Check curb alignment during pouring

VI. Reinforcing Steel

A. General

As the name implies, reinforcing steel is that steel used to strengthen structural members. It is used in the form of steel bars, plates, wire and wire mesh. Railroad rails and structural shapes such as channels and beams, have been, and are being used. Reinforcing steel is required primarily to take tension stresses in members not particularly adaptable to such stresses and has been used in the form of strap iron fastened securely to the bottom of wooden beams and as bars in reinforced concrete. Steel is particularly adaptable for use as reinforcement in concrete masses, as the coefficient of expansion for steel and concrete is practically the same. It is imperative that the reinforcing medium and the structure being reinforced have approximately the same rates of expansion and contraction; otherwise, separation of the two will result from temperature changes. While concrete has some actual value in tension, this material is not considered in design, and consequently, some material must be substituted to take the tensile stresses that are to be carried by the member.

B. Specification Requirements

Item 440 of the Standard Specifications set out the detailed requirements for Reinforcing Steel to be used in structures.

1. Materials

The specifications make no distinction in the use of rail steel, axle steel or new billet steel. New billet steel is that steel that has been rolled from new billets of properly identified heats of open hearth, basic oxygen or electric furnace steel. Re-rolled material cannot be considered new billet steel and will not be accepted as such. Rail steel is steel rolled from standard section tie rails, and is more brittle than new billet steel. When rail steel is used in a structure, it shall meet the bend requirements for hard grade billet steel as specified in ASTM Designation A-15. Axle steel falls in the same category as rail steel insofar as handling is concerned.

The specifications require that all reinforcing steel shall be deformed bars, unless otherwise designated on the plans. Deformed bars are those bars having small deformations on their surface to increase the bond strength between the steel bar and the surrounding concrete. The net sectional area of a deformed bar must be equal to the net sectional area of a plain bar of the same nominal size. Square, twisted bars are not considered deformed and shall not be used.

2. <u>Fabrication</u>

The reinforcement shall be bent cold to the various shapes shown on the plans. All bending of hard grade and rail steel bars shall be done in the shop. Bending of other grades shall preferably be done in the shop.

Item 440.4 sets out the acceptable tolerances to be used in fabricating the bars. These tolerances are shown in Figure VII.

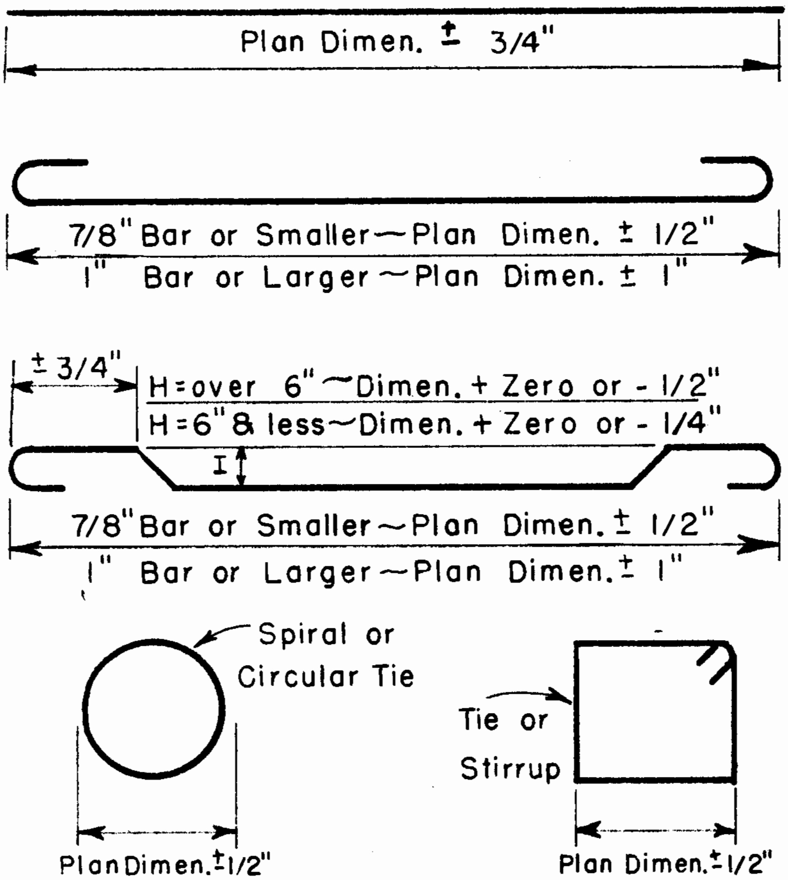


FIG. VII

3. Handling

Proper storage of reinforcing steel is essential. The primary requirement for such storage is to keep the steel clear of the ground and vegetation, away from constant moisture, and protected from injury by foreign materials. The specifications require that reinforcing steel be stored above the ground on suitable platforms, skids or other supports, and protected from mechanical injury or rust. The steel should be sufficiently clear of the ground to permit free circulation of air underneath the stockpile. If the Contractor contemplates any appreciable delay before using the material in the work, it may be to his advantage to cover it with suitable cover for protection against the weather and against rusting.

Rusting is generally noted in two stages. The initial rusting is easily detected by its light orange appearance and powdery composition. The secondary rusting shows a dark brown color and usually flakes off in rust scales. Unless the light, orange-colored rusting covers the steel bars completely, it will not usually be detrimental to the bonding strength of the bar. If desired, this light rusting can be removed easily by brushing with burlap rags. Tightly adhered scale or rust which resists removal by vigorous wire brushing need not be removed except that excessive loss of section to the reinforcement due to rust shall be cause for rejection. Excessive loss of section is defined as loss of section to the extent that the reinforcement will no longer meet the physical requirements for the size and grade of steel specified.

4. Placing

Reinforcement shall be placed as near as possible in the position shown on the plans. When structural designs are made, each bar is spaced in a manner to utilize that bar to best advantage. When this spacing is changed in the field, the Engineer has no way of determining stress changes, unless he calculates the design of that particular section. In the plane of steel parallel to the nearest surface of concrete, bars shall not vary from plan placement by more than one-twelfth of the spacing between bars. In the plane of the steel perpendicular to the nearest surface of concrete, bars shall not vary from plan placement by more than one-quarter inch. Cover of concrete to the nearest surface of steel shall meet the above requirements but never less than one-inch cover shall be provided.

Concrete blocks and approved galvanized metal spacers are permitted by the specifications to aid in the proper spacing of reinforcing steel.

Pre-cast mortar or concrete blocks to be used for holding steel in position shall be cast in approved molds and cured until they can be removed. After removal from the molds, they shall be immersed in water for the remainder of at least a four-day curing period. Forms used in moding concrete or mortar blocks should never be oiled. They may be soaked in water prior to their use, but form oiling invariably causes the concrete blocks to be slightly oily, and this oil will sweat through the structure surfaces and leave oily squares to mar the finished appearance. The blocks should be cast in such a manner that the size of the block increases away from the area to be placed against the forms. A suitable tie wire shall be provided in each block to be used for anchoring the block to the steel.

Since these blocks are used to hold the steel in position adjacent to formed surfaces, they must be cast accurately to the thickness required.

C. Inspection of Reinforcing Steel

1. General

Under our present system of inspection procedure, commercial laboratories inspect steel at the point of manufacture. When the laboratory notifies the Department of acceptance of the steel, acceptance slips are sent to the field engineer. The steel fabricator usually sends a bar list direct to the Contractor. A copy of the bar list shall be secured by the Inspector, checked against the plans, and used as a checklist for the shipment. The inspection made by the commercial laboratories does not cover the fabrication or bending of the steel. Their inspection only covers the quality of the metal, itself, size of the bars, and weights on different-sized bars. The receipt of approved acceptance slips or tests reports does not relieve the Engineer of the responsibility for the materials, and while he has no opportunity to check the actual steel composition, he can check the fabrication of the steel and the test results against the plan and specification requirements. The steel must be checked for bending mill scale, rust, or any harmful defects or coatings that might exist.

2. Fabrication

Upon receipt of a shipment of reinforcing steel, the Inspector's first step is to identify the various bundles of bars and correlate them with the bending diagrams shown on the plans. The bundles must then be broken and random checks made on the dimensions of several bars in each bundle to see if the shape and size of the bars meets the tolerances set up for bending. (Figure VII.) While it is not usually necessary to check each and every bar, enough bars should be measured to satisfy the Inspector that a representative sample has been checked. It is conceivable that each bar will have to be checked, particularly if some of the bars are failing to meet the specification and plan requirements. However, this is not the usual case. The bars, usually, are bent similarly and will tend to be alike. As pointed out above, this is not necessarily true, and the Inspector must exercise judgment in determining how many of each type bar to check.

Bars which are acceptable should be noted in order that the acceptance slip may be signed by the Engineer. Those that are not acceptable should be noted and segregated physically from the acceptable steel. The Contractor should be instructed, in writing, that these certain bars are not acceptable, the reason given, and he should be directed to remove them from the jobsite.

3. <u>Storing</u>

The Inspector should pay strict attention to the methods used by the Contractor in storing the steel on the jobsite. The normal procedure is to unload the steel at the various structure sites. While this is the Contractor's responsibility, the Inspector should satisfy himself that the bars at each site are the proper ones for that structure and no errors in unloading have been made.

One of the most frequently violated specification requirements for reinforcing steel is the storage rquirement. To simply pile several thousand pounds of steel on two-by-four runners in deep grass or weeds is not in accordance with the specification requirements. The storage area should be thoroughly cleaned of vegetation and be well-drained. Four-by-four timbers are the minimum size recommended for blocking. In the event large quantities are involved, four-by-six timbers are recommended. Sufficient runners should be used to preclude the steel from sagging between the supports. Inspectors should insist from the beginning that proper storage methods be used, and then many future problems will be eliminated.

4. <u>Placing</u>

The Inspector should be present during the placing of the reinforcing steel. In this way, he may observe the layout methods used by the Contractor and be able to advise the Contractor in the event problems come up.

In this way, mistakes and errors are caught at once and can usually be corrected easily. It should be stressed that the Inspector is merely an observer, and the entire responsibility for the correct placement of the steel remains with the Contractor. The presence of an Inspector at this stage is a convenience to the Contractor and in no way relieves him of responsibility.

All phases of the placement of the steel should be thoroughly checked prior to pouring concrete, and then continuous checks on the position of the steel should be made during the concrete pour, in order to see if the steel has changed position.

D. Records to Keep

1. Record of Receipt

A receiving record of each shipment of reinforcing steel must be kept in a bound field book. This record must show the following:

a. Date received

b. Amount received

c. Producer

d. Tested by and Lab. No.

e. Number and length of each size bar

The identification tag on each bundle of steel should be carefully noted, as this is the only way of correlating shipments with test reports. When the Engineer has satisfied himself that the steel received is acceptable and meets specification requirements, he must complete the date shown on the acceptance slips and forward them through proper channels.

2. Record of Amount used

Records must be kept that will reflect the number, kind, size, and amount of reinforcing steel used in each part of the structure. The lengths and numbers of bars should be listed and the weights calculated. These records must be kept in bound field books.

When a project is completed, the Engineer should balance the steel received against the steel used and on hand, to see that no large errors have been made. The amount of steel left on hand should be carefully noted and its probable destination determined.

E. Inspector's Checklist

1. Upon receipt of a bar list from the fabricator, check against plans.
2. Check shipment against bar list.
   a. Identify bundles and correlate with plans.
   b. Note omissions and additions to and from bar list.

3. Check bending and fabrication.

4. Check storage methods of steel.

5. Record receipt of steel in Materials Received Book Locations on jobsite should also be noted.

6. Check concrete or mortar blocks.

   a. Curing

   b. Size

   c. Tie wires

7. Check condition of steel prior to using.

   a. Rust

   b. Physical damage

   c. Correct bars

8. Check placing of steel in structure.

   a. Layout work

   b. Proper blocks and spacers

   c. Placement within tolerance

   d. Tied at each intersection

9. Check position of steel during pouring.

10. Record amount of steel used in field books.

VII. Mixing, Placing, Curing and Finishing Concrete

A. Mixing and Mixing Equipment

1. Job Mixed Concrete: Job mixed concrete is that concrete mixed in an approved batch mixer in accordance with the requirements of Item 421 of the Standard Specifications, adjacent to the structure for which the concrete is being mixed. It is moved to the placement site in carts, barrows, concrete buckets, etc.

a. Weighing and Measuring Equipment: Weighing and measuring equipment shall conform to Item 500. This item gives the detailed requirements for the scales and other equipment used in measuring the materials in concrete batches.

Job mixed concrete requires the use of portable platform scales, usually the Type B scale. The specifications appear rather elaborate concerning weighing devices, but this was done purposely for the benefit of the Inspector and the Contractor. Many contractors are not familiar with scales and weighing devices. In passing on the adequacy of any weighing device, remember that the purpose of the specification on weighing devices is to secure proper batching of the aggregates, and the decision should be based on the ability of the weighing mechanism to properly perform that function. Before scales are put to use, they should be leveled and checked for accuracy. This check can be made with standard 2#, 5# and 50# test weights. Accuracy within 0.4 per cent of the total load being weighed will be within proper tolerance. The accuracy of these scales should be checked at regular intervals to be sure their adjustment has not been changed by handling and usage.

b. Mixer: When checking the mixing equipment, it should be born in mind that this equipment is the most important machinery used in the entire process of concrete production and should be examined accordingly. Inspection should include such items as the timing device, speed regulator, water-measuring device, and blades, discharging mechanism, motor, skip raising cables and all parts that might cause defective concrete or placing delay. Attention is directed to Item 421.11, which states that "All equipment, tools and machinery used for hauling materials and performing any part of the work shall be maintained in such condition to insure completion of the work under way without excessive delays for repairs or replacements." These are not quoted to encourage unreasonableness or arbitrary decisions, but rather to impress on all concerned that the mixing equipment must be adequate and must fulfill its function.

The timing device on the mixer is described in Item 421.11 as follows: "The concrete mixer shall be equipped with an automatic timing device so constructed that it is put into operation when the skip is raised to its full height and dumping. This device shall lock the discharging mechanism satisfactorily to prevent emptying of the mixer until all the materials have been mixed together for the minimum time required, and it shall ring a bell after the specified time of mixing in the drum has elapsed." This mechanism should be checked when the mixer is running. These devices can get out of adjustment and should be checked at regular intervals. Some timing devices are tripped by the skip as it comes up to dump the batch, and others as the skip starts its downward travel. Remember that the mixing time is to be set after all ingredients have entered the drum.

The water measuring device must measure the amount of water accurately. A rule of thumb is that the device should be accurate within one per cent of the set amount. A simple method of checking this device is to set some arbitrary quantity of water on the meter, run this water into some container and weigh on the aggregate scales. The accuracy of these scales must be known, as they may be in greater error than the water measuring device, itself. This check should be made while the mixer is running. The cut-off valves must work in a manner to prevent a continual, small dribble of water entering the drum during the mixing period. The accuracy of this device should be checked at frequent intervals, as moving the mixer from one location to another may change its performance.

The skip should be checked for cleanliness; the condition of the raising cables should be noted, and provisions against spillage of materials entering the drum should be adequate. Skips that spill a constant stream of material as the batch enters the drum are not adequate. The drum of the mixer should be examined for leaks and old, hardened concrete. Mixers that have been in use for a long period of time usually develop leaks and such leaks are detrimental as the material lost is usually cement grout.

A visual inspection of the drum should be made before every placement to be sure it is clean and free from all old concrete. If concrete is allowed to start fouling a drum, it will accumulate rapidly and eventually reduce the mixer capacity. In summer weather, it may be necessary to stop a long placement for a short time and clean the drum.

The discharge mechanism from the drum should be examined carefully, as old mixers usually leak grout between the discharge ring and the discharge chute. Grout leakage should not be allowed, and a new discharge ring and chute may be necessary to stop such leakage.

The specifications require that pick-up and throw-over blades in the drums of the mixer which are worn down over ten per cent in depth shall be repaired or replaced by new blades.

c. <u>Placing Equipment:</u> In handling concrete placing operations, many different types of placing equipment is used. Each contractor has his own favored equipment and method, and some jobs require particular equipment for economical operation. Concrete carts or buggies are used. The runway arrangement for these carts and buggies should not interfere with the normal finishing operation.

Item 420.11 gives complete details on the use of chutes, troughs and pipes in placing concrete.

2. Ready-Mix Concrete: Ready-mix concrete shall be concrete mixed in accordance with Item 502 of the Standard Specifications. It shall be mixed and transported by one of the following methods:

(1) Mixed completely in a stationery mixer and transported to the point of delivery in a truck agitator or a truck mixer operating at agitator speed. (Central Mix Concrete)

(2) Mixed partially in a stationary mixer with the mixing completed in a truck mixer and transported to the point of delivery at mixing and agitating speed. (Shrink Mix Concrete)

(3) Mixed completely in a truck mixer and transported to the point of delivery at mixing and agitating speed. (Transit Mix Concrete)

The general principles involved in the portion on job-mixed concrete are equally applicable to ready-mix concrete. There are some specific items involved in the use of ready-mix concrete that are not covered in the job mix portion, and these items will be covered below.

a. Weighing and Measuring Equipment: Weighing and measuring equipment shall conform to the requirements of Item 500 of the Standard Specifications. This item gives the detailed requirements for the scales and other equipment used in measuring the materials in concrete batches.

Ready-mix concrete requires the use of aggregate batching scales, usually of the suspended hopper type. This type consists of a weighing container or hopper completely suspended from the scale equipment. The scale equipment must have suitable provisions for leveling.

The appliances used for placing materials within or upon the scales shall so regulate and control the supply of materials that accurate adjustment to required weights can be accomplished rapidly and efficiently. A convenient means shall be provided for the addition as the removal of small amounts of material to adjust the quantity to the exact weight per batch.

The scales used for weighing aggregates shall be equipped with a quick adjustment at zero to provide for any change in tare. The scales shall be provided with pointers or "tell-tale" indicators of the springless dial type to indicate full load for each aggregate. The dial or "tell tale" devices shall be in full view of the operator while charging the weigh box and he shall have convenient access to all controls.

The cement weighing equipment shall be of rugged construction. Provision shall be made for indicating to the operator that the required load in the weigh box or container is being approached. This device shall indicate the last 50 pounds of load. If a closed type weigh box is used, the cement weighing scales shall be provided with a springless dial to indicate when the weigh box is empty. This indicator shall be in continuous operation. The weigh box shall be provided with an approved vent, a tightly covered inspection opening of not less than twelve inches by twelve inches, and the box and scales shall meet the requirements for accuracy of weight.

b. <u>Mixers:</u> Item 502 sets out the detailed requirements for mixers and agitators. In addition to the points covered under job-mixed concrete, ready-mix concrete entails additional requirements.

Mixers may be stationary mixers or truck mixers. Stationary mixers shall meet the requirements of Item 421, set out above in job-mix concrete.

The drums of truck mixers shall be activated by an engine mounted as an integral part of the mixing unit for the purpose of rotating the drum. It shall be capable of being governed accurately for the desired speed of rotation and be in satisfactory working condition. As an exception, where the truck mixer is equipped with a transmission that will govern the speed of the drum within the specified r.p.m., no separate engine for rotating the drum will be required.

Truck mixers shall be equipped with facilities to reaily permit access to the inside of the drum for inspection, cleaning and repair. They shall be examined daily for changes in condition due to accumulation of hardened concrete or to wear of blades. Blades shall be replaced when any part or section is worn more than ten per cent below its original height. Any accumulation of hardened concrete shall be removed and any excessively worn blades shall be replaced before the mixer will be permitted to be used.

Each truck mixer shall have attached, a metal plate on which are marked the various uses for which the unit is designed. This data shall include the drum speed for batch mixing and agitating, the capacity of the unit for complete mixing, for partial mixing, and for use as an agitating unit only.

Truck mixers shall be equipped with activated counters by which the number of revolutions of the drum may be readily verified. The counters shall begin counting at the time of beginning the mixing cycle at mixing speed.

c. <u>Operation of Plant and Equipment:</u> Item 502.7 covers in detail the various requirements for the operation of a ready-mix plant and related equipment.

This item gives the various minimum mixing times and mixing conditions. Strict adherence to these requirements should be observed.

It is essential that the general intent of production and delivery of a continuous flow of ready-mixed concrete be attained. In no case, shall more than twenty minutes elapse between the depositing of successive batches of concrete in any monolithic unit.

An approved ticket system for recording the transportation of batches from the plant to jobsite shall be maintained by the Contractor.

B. <u>Placing Concrete</u>: Items 421.11, through Item 420.18 give the detailed requirements for the placing of concrete in structures under varying conditions and circumstances. No attempt will be made in this course to go into all of the special and detailed requirements. General requirements that are equally applicable to all situations will be covered, and the Inspector is cautioned that he should familiarize himself with all of the other specialized requirements.

1. <u>General</u>: As pointed out previously, all form and steel inspection shall have been completed and approved prior to beginning any concrete placement operation. The specifications definitely prohibit the beginning of concrete placement operations until the completion of the formwork and reinforcement placement in the particular unit concerned.

   In general, concrete mixing, placing and finishing shall be done in daylight hours. The work should not begin when it is evident that it will not be completed before dark, unless adequate provisions are made to light the entire site of all operations.

Concrete placement will not be permitted to begin when impending weather conditions may result in rainfall or low temperatures which will impair the quality of the finished work. The Inspector is cautioned against being overzealous in these matters. In making a decision of this character, the time required for the placement, the general weather conditions, the amount of work that will be stopped if no placement is made, and the equipment available should be considered.

If caught in a rain, the concrete in the forms and buggies should be kept covered. If it is at all possible, the material stockpiles should be covered. The water content of the concrete batch will have to be temporarily controlled at the mixer with appropriate adjustments on the weights of material.

Specification requirements limit the free fall of concrete to three feet, except in the case of thin walls, such as culvert walls. The purpose of this requirement is to preclude the possibility of separation and segregation of the concrete and displacement of reinforcing steel. The fall of concrete is also limited to keep from spattering the reinforcing steel and forms. This coating forms a layer of undesirable material that, if permitted to accumulate, will make a thin, porous layer of grout exposed to the atmosphere, which will harden rapidly if not removed. This hardened grout reduces the bond strength between the concrete and steel, and in the case of forms, will produce a surface which spots and scales easily.

Each part of the forms shall be filled by depositing concrete as near its final position as possible. The sequence of placing the concrete in the structure shall be as shown in the plans or specifications. Depositing large quantities of concrete at one point in the forms and running or working it along the forms will not be allowed. If concrete is placed in this manner, voids and honeycombed areas are certain to occur. This can become a particularly annoying point with the Contractor, because in the case of long structures, a great deal of scaffolding might be required to provide means to place the concrete without running it along the forms. As a result, the tendency is for the Contractor to largely ignore this point, if it is not called to his attention by the Inspector.

If chutes, troughs or pipes are used as aids in placing the concrete, they should be so arranged that the concrete will not become segregated as it slides down. This will necessitate baffle boards or switchback chutes in the case of steep slopes. All such aids to placement shall be kept free of coatings of hardened concrete. Normally, a limit of 35 feet in length is applied to these aids, unless the Engineer authorizes greater lengths.

Landing boards can be used at the ends of chutes and troughs to keep the concrete from churning into soft footing material, and the concrete can then be shoveled from the landing board to position.

All concrete is required to be compacted and flushed by continuous working with mechanical vibrators of an approved type. Vibrators that fasten to the forms or to the reinforcing steel are not allowed to be used. Vibrators are particularly conducive to causing concrete flow, and as a result, the Contractor may tend to try to work the concrete along the form, thus violating the point set out above which specifically prohibits such procedure.

The proper use of a vibrator in concrete results in a dense, well-compacted mass of concrete. Improperly used, a vibrator can cause segregation. If a vibrator is held in one spot too long, it will cause a "sand spot" which is simply an area of segregation. The Inspector should give careful attention to this operation and by observation, determine if the vibrator is being operated properly. A stand-by vibrator should always be present on the job.

2. Placing Concrete in Cold Weather

Item 420-12 covers this point in detail. As a general requirement, no concrete shall be placed when the atmospheric temperature (taken in the shade away from artificial heat) is below 40°F, without permission of the Engineer. If such permission is granted, the aggregates and/or water shall be heated uniformly in the manner set out in Item 420.12.

In the case of a drop in temperature below 40° when the concrete is less than three days old, the concrete must be covered and protected as outlined in Item 420.12. The most critical time is that period between the initial and final set. Concrete frozen during this period cannot be reclaimed. Concrete frozen before the initial set can possibly be thawed and cured, but will never be as strong as regular concrete. Aggregates used from large stockpiles that have been subjected to freezing temperatures may contain frost or frozen particles. The surface of the stockpile may apparently be in good condition, while the interior may contain frozen lumps. No frozen aggregate should be used.

3. Placing Concrete in Hot Weather

Placing concrete in hot weather is complicated by the fact that heat will cause the initial set of concrete to begin much sooner than under ordinary conditions. Thus, the time interval between the introduction of the mixing water and the placement of the concrete in the forms becomes critical. This is particularly true in the use of transit-mix concrete where some hauling time is involved.

Item 420.13 of the Standard Specifications sets out the detailed requirements in this regard. Also covered is the use of cement dispersing agents to retard the initial set. The maximum time intervals between the introduction of mixing water and the placement in the forms is also set out. Inspectors are cautioned to review these time intervals in order to avoid overrun of time and consequent loss of concrete batches.

4. Placing Concrete in Box Culverts

Item 420.17 covers the placement of concrete in box culverts. In addition to the general points covered above, the following items are applicable to small structure placements in box culverts.

Inspectors are reminded that construction joints in the various parts of a culvert are allowed only at the points shown on the plans. Curbs are placed monolithic with the top slab.

C. <u>Curing and Form Removal</u>

1. <u>Curing</u>

Item 420.21 deals with the proper curing of all concrete. In addition to other details, the minimum number of curing days required on various structures are given. Inspectors should insist on rigid adherence to these items.

All concrete except as noted in Item 420.21 shall be cured for a period of four days. In the event forms are removed in less than four days, curing shall continue by other means until the four-day period is up.

Concrete that is improperly cured is generally worthless. Concrete must have warmth and moisture to properly complete its chemical reaction. Some water enters into the concrete to complete the hydration of cement particles after placing. Lack of water for this operation will not permit the proper completion of the chemical action. <u>The curing medium must be in direct contact with concrete</u>. A great many structures are draped like statues ready to be unveiled, and this practice is specifically prohibited by the specifications.

There are several alternate methods of curing provided for in the specifications, subject to various restrictions as outlined in Item 420.21. These methods are:

a. Form curing

b. Water curing

    (1) Wet mat

    (2) Water spray

    (3) Ponding

c. Membrane curing

d. Elevated temperature curing

When forms are left in conctact with the concrete, these surfaces will not require other curing methods.

When forms are removed from concrete before it has completed its curing period, one of the alternate curing methods must be used.

a. <u>Wet Mat Curing:</u> In every case, mats should be wet prior to placing on the concrete. After mats have been used for some time, they accumulate a film of dirt, clay, and sometimes, grease, on their outer surface, that is more or less impervious to water. For this reason, if the mats are placed dry, and then wetted, they will not provide readily accessible moisture for the concrete. Wet mats are heavy and hard to handle, and the natural inclination is to place them dry. It is highly important that these mats be placed wet. With most curing, there is a tendency to turn back these mats for various purposes and such violations of curing practices should not be permitted. The concrete should not be allowed to become dry at any time during its curing period.

b. Water Spray Curing: Water spray curing is simply another means of keeping the concrete wet during its curing period. It is not often used, but if done properly, satisfactory results will be obtained.

When water spray is used, the curing is accomplished by overlapping sprays so that all concrete surfaces are continuously wet. Prior to beginning water spray curing, a proper drainage plan for runoff must be considered. This is particularly true if roadbed areas are involved. Water which stains or leaves unsightly residue shall not be used.

c. Ponding: Curing by ponding methods is permissible on roadway and sidewalk slabs, and top slabs and footings of culverts, providing the entire surface is covered. In cases where roadway expansion joints are involved, the dam should be built as close to the joint as possible and should be built on a double layer of mat to eliminate the dry area next to the joint.

d. <u>Membrane Curing:</u> When this type of curing is permitted by the specifications, Type II white pigmented curing compound shall be used. Coverage shall be as required in Item 531, Membrane Curing. Membrane which becomes broken shall be corrected immediately by reapplication of membrane.

2. <u>Form Removal</u>

Item 420.22 of the Standard Specifications sets forth the detailed requirements governing form removal. This specification sets out in detail the various minimum times when forms may be removed. Strict observance of these time limits should be enforced.

A schedule of form removal times should be prepared for each structure unit as it is erected in order to avoid errors. No forms should be removed without express permission. The Contractor should be cautioned about the rough handling of forms, particularly those forms which are to be used again on exposed surfaces. The use of nail bars for removal of forms is barred by some Contractors because of the damage which may be done to the edges of the form lining. Nail bars may do serious damage to chamfer lines and concrete surfaces when carelessly used.

D. Finishing Concrete

1. General

In finishing the tops of curbs, walks, caps, posts and walls, the following general procedure is used. The concrete is struck off and finished with a wooden float and such special treatment given the surface as is required. Some contractors try to use a mortar topping on posts and other units, but this method introduces the possibility of planes of cleavage between the concrete and mortar topping. The specifications definitely prohibit the use of mortar topping for these surfaces.

When concrete has been brought to the level of a construction joint, those areas that are to be covered by a successive placement are not usually finished. Such concrete should be allowed to take an initial set and be firm enough to support a man's weight before any attempt is made to clean the laitance from the surface. Experienced contractors are willing to clean such laitance from the surface of the concrete at this time rather than to delay it until it must be removed with chipping tools.

Any type of fiber or steel brush will do this work effectively.

The tops of concrete footings, while not requiring elaborate finishing should be struck off and hand-floated. Where at all possible, the horizontal surfaces should be given a slight slope for drainage purposes.

The top surface of culvert footings should be hand-floated either by hand wood floats, or long-handled floats. The top surface of culvert barrels that do not carry direct traffic, should be given the same finish.

After floating and before the finish has set, all horizontal surfaces except sidewalls and roadway slabs should be striped lightly with a fine brush to remove the surface cement film, leaving a fine-grained, smooth but sanded texture.

2. <u>Finishing Exposed Surfaces</u>

Item 420.24 of the Standard Specifications gives the various types of surface finishes to be used. This item also sets out the areas to which each type finish is to be applied. Inspectors should be familiar with the types of finishes and the areas to which they are applied.

The first rubbing of concrete surfaces should develop an appreciable depth of grout. This grout should be worked out of the concrete surface itself, and should not be applied in the form of mortar. Curing of the first rub is essential and if done properly, will result in a resetting of the material developed from the concrete surface.

The second rubbing should not disturb the full depth of the first rub, but should merely smooth its surface. Surface rubbing will be difficult when forms are held on concrete surfaces for an appreciable length of time. In extreme cases, it may be necessary to use some mortar to be able to finish the surface properly. The permission to use such mortar should be granted only by the Resident Engineer.

3. <u>Patching</u>

Item 420.23, Defective Work, covers the patching and repair of defective work and honeycombed areas.

This is a subject that sometimes receives little attention. The loose material in honeycombed areas should be removed until solid concrete is in evidence at all points, and the limits of the area should be cut to avoid feathered edges. This area should be washed clean and kept wet for several hours. After being soaked, the surface should be painted with neat cement and water of a fluid consistency. (Either a latex base or epoxy base patching adhesive can be used in areas where the size, location of depth warrants.) Retempered mortar or concrete, depending on the size and character of the patch, should then be rubbed into all crevices by hand. This rubbing forces out air pockets that otherwise will be left between the old concrete and the patching material. After all the old concrete has been covered by this rubbed-in grout, the remainder of the hole should be filled and the whole area rammed and packed with the mortar or concrete.

The properly retempered mortar should be mixed somewhat wetter than usual concrete and allowed to stand for approximately one hour. This time will depend on weather conditions. In hot, dry weather, thirty to forty minutes may be sufficient, while in cool, damp weather, the material may require as much as two hours. The mortar should be stirred and mixed occasionally during this period. The purpose of allowing the mortar to set is to permit it to take all or a large part of its initial shrinkage. At the end of the tempering period, the mortar should have attained a workable consistency. The addition of water to the tempered material before placing is not desirable. This filling material should be as dry as possible without being crumbly.

Horizontal patches should be tamped thoroughly and hand-finished. Patches on vertical surfaces should be held in place by tightly-wedged forms until they have taken a final set. As soon as possible after patching, the area should be cured for the full length of a regular curing period.

The earlier concrete is patched, the better the chance of success, as it is very difficult to patch the old concrete successfully. Holes left by form ties should be filled immediately after removal of the forms. Patching and pointing should be done prior to the initial rub.

STRUCTURAL CONCRETE INSPECTORS' SCHOOL

PART II - LARGE STRUCTURES (BRIDGES)

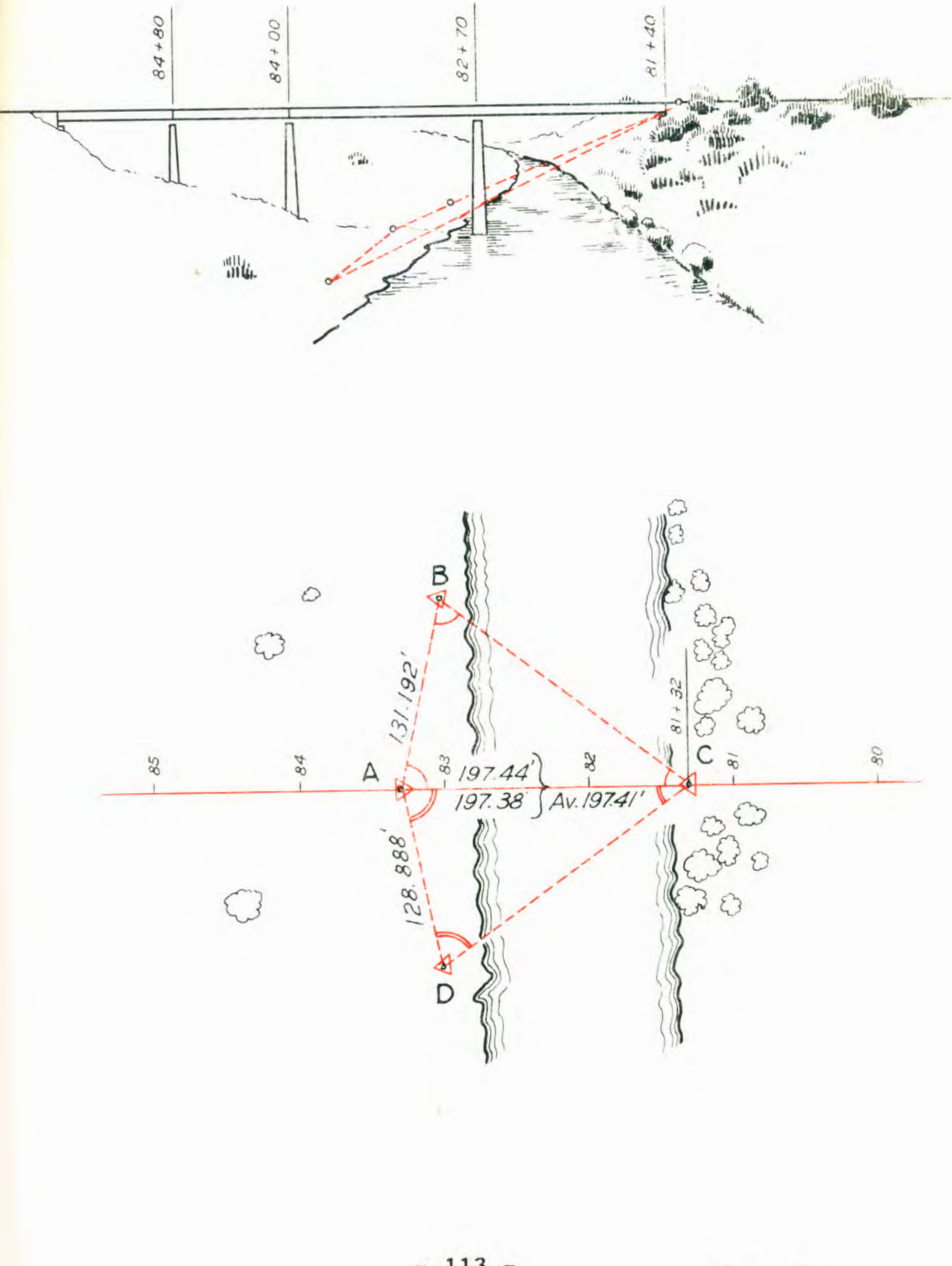
I. Measurements and Layout Work

A. General

A bridge structure is designed to be placed at a definite location in order to span a desired area. Since the design elements of a bridge are very critical, it is necessary that the structure be built exactly as designed. The supporting piers, for example, must be built in the proper position. The roadway slab must be the proper thickness or failure will result. While this is essentially true in all parts of highway construction, it is especially critical in bridge construction. It is absolutely necessary that measurements be accurately made; however, the physical location of the bridge structure may vary somewhat without detriment to the project as a whole. The lines and grades and all measurements within the limits of the bridge must be accurate. The larger and more complex the structure, the more accurate the measurements must be.

The location and grades for any structure are established on the ground by construction stakes. Placing of these stakes by the field forces is one of the steps in the completion of a structure that does not receive an independent review and check prior to use. For this reason, all construction stakes and reference stakes must be placed carefully and accurately to avoid errors which, if not detected, may result in costly changes in the structure to secure satisfactory completion. It is advisable that the field party be composed of men whose training will permit the exchange of duties within the party in order that each measurement may be checked by different members of the group. By virtue of custom rather than by definite specification, contractors accept the stakes and grades set by the Engineer as being correct unless they are warned to do otherwise, either by past experience or by the Engineer who is willing to admit he might make a mistake. Some contracting organizations employ an engineer who is capable of checking the stakes and grades and is able to set additional stakes to expedite the work. When such a man is present, proper cooperation by the Resident Engineer's forces may afford opportunities to appreciably reduce the work of the field party.

Direct measurements along the centerline of the bridge should be used whenever possible. It is possible on most Texas stream crossings and on overpass structures. Since no one set of rules or procedures can be established, each structure presents a different problem and challenge to the Engineer. Before laying out a structure, the Resident Engineer should have qualified personnel make independent checks of the bridge plans and prepare sketches and field books containing the lines and



84+80
84+00
82+70
81+40
B
131.192'
A
197.44'
197.38'
Av. 197.41'
81+32
C
128.888'
D
85
84
83
82
81
80

FIG. I

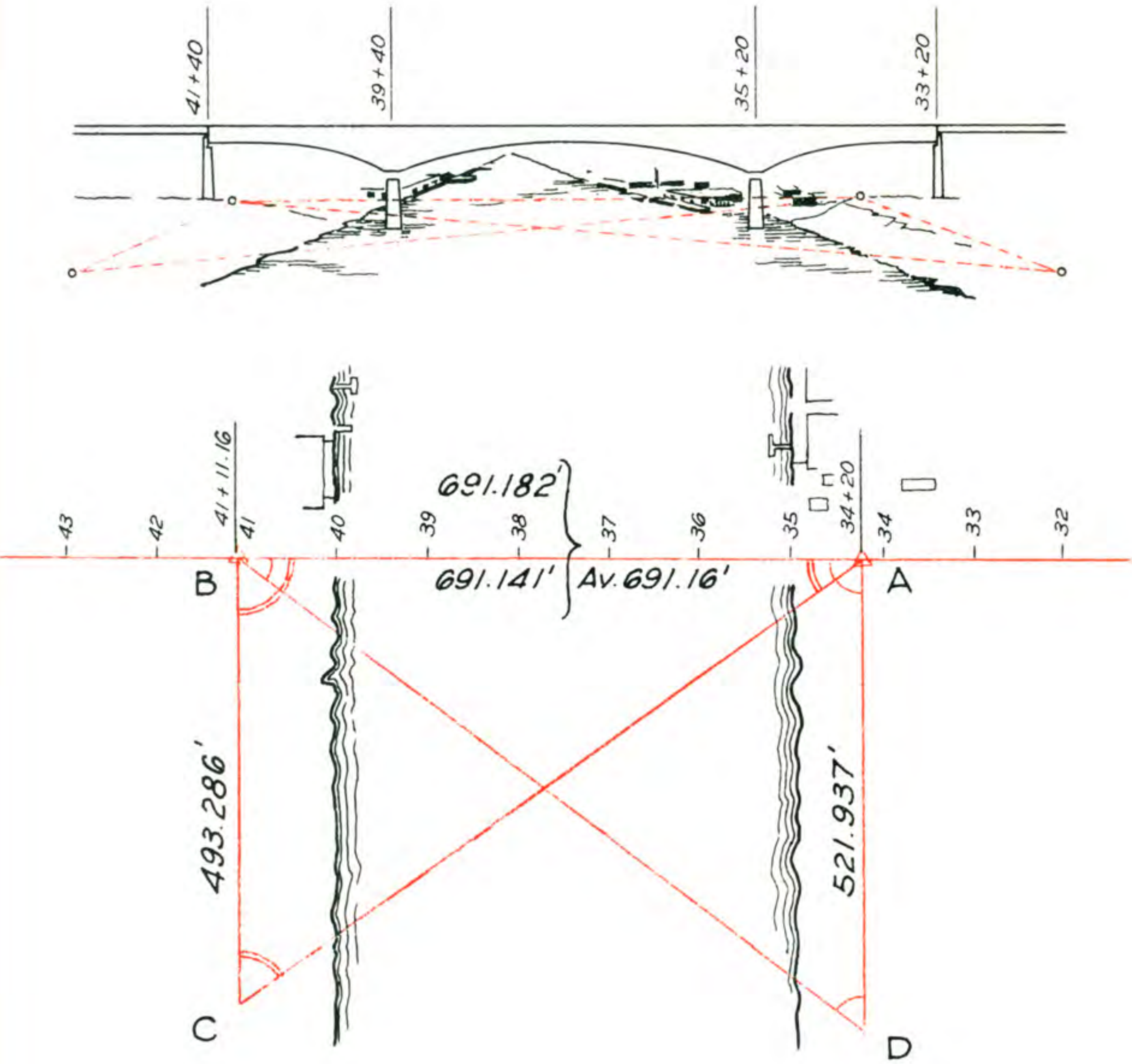

41+40
39+40
35+20
33+20
41+11.16
34+20
43
42
41
40
39
38
37
36
35
34
33
32
691.182'
691.141'
Av. 691.16'
B
A
C
D
493.286'
521.937'

FIG. 2

grades to be used in construction of the structure. The bridge is actually built from lines, reference points, and bench marks established on the ground. Experienced personnel should be used to establish these points.

B. Triangulation

Where wide bodies of deep water must be crossed or where high, steep banks exist, measurements by triangulation should be used in locating the extremities of the bridge in each bent location.

In its simplest form, triangulation is needed to obtain a correct measurement of distance across a piece of terrain where ordinary use of a steel tape cannot be made but where such use of a tape can be made on both sides of the trouble area. Two such instances are shown in Figure 1 and Figure 2.

In Figure 1, the chainage was carried to station 81+32 which was as near the top of the bluff as an instrumentman could work comfortably. The centerline was shot ahead and a hub "A" was set from which two base lines could be laid off and easily measured. Vegetation on top the bluff precluded using base lines from station 81+32.00.

Baseline AB was measured. Angles at A, B, and C were read by repetition and the triangle closed within 8.3". The length of AC was computed to be 197.44'. By similar operation from triangle ADC, the length of AC was computed to be 197.38'. The average of these is 197.41' which, added to station 81+32, gives 83+29.41 for the station of Point A. From this point, regular measurements were resumed.

In Figure 2, the hub "A was set at a point where baseline A-D could be laid off for satisfactory working conditions. This was at station 34+20.00. The line was prolonged and hub "B" was set at a point where base line B-C could be laid off for satisfactory working conditions. Wharves and shell storage on the opposite side of the centerline prevented having two baselines on one side of the stream.

In triangle ABD, the base line AD was measured and the angles at A, B, and D were read by repetition and closed within 5". The distance AB was computed to be 691.182'.

In triangle ABC, the baseline BC was measured and the angles A, B, and C were read by repetition and closed with 4". The distance AB was computed to be 691.141'. The average AB is 691.16' which, when added to 34+20.00, gave the station of hub "B" 41+11.16. From there, measurements by normal methods were resumed.

In both of the instances mentioned above, only two field operations are involved, accurate measurement of the baseline and accurate measurement of the angles. The two baselines are used as a check.

The following points should be considered and evaluated in making a baseline layout.

1. Accurate results, to the practical tolerance which is set, are necessary.

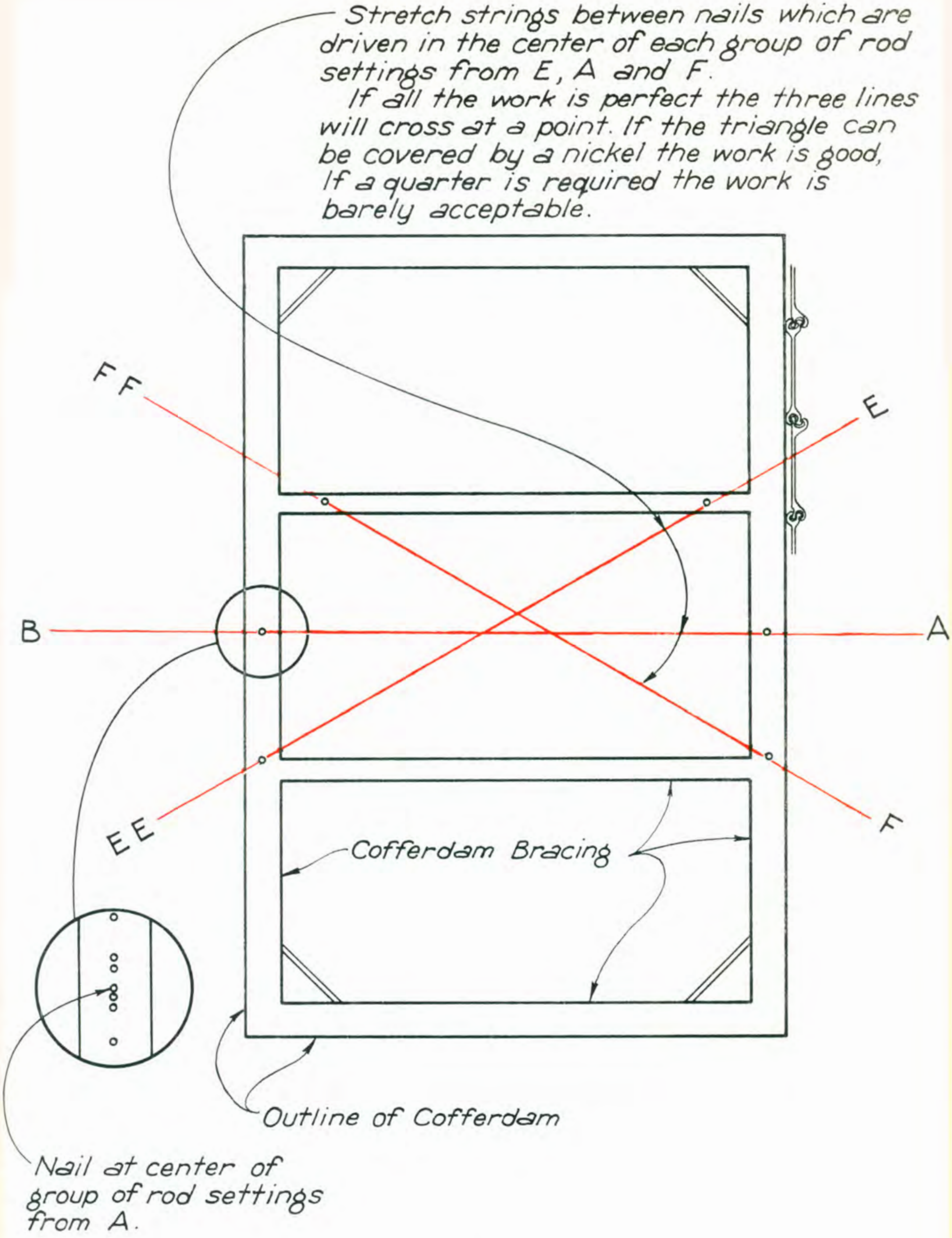

Stretch strings between nails which are driven in the center of each group of rod settings from E, A and F.
If all the work is perfect the three lines will cross at a point. If the triangle can be covered by a nickel the work is good, If a quarter is required the work is barely acceptable.
FF
E
B
A
EE
F
Cofferdam Bracing
Outline of Cofferdam
Nail at center of group of rod settings from A.

FIG 3

A baseline may be abandoned after it has served its purpose of:

a. Determining the cross-river distance, and

b. Setting hubs for use in establishing the location of piers in the river. This may permit its location in areas where working conditions are good and where the cross-river distance will be shortest.

The angle between the baseline and the bridge centerline should be as small as good working conditions permit. It may be smaller than 90° and will often be greater than that.

The baseline should then have a length about equal to the cross-river distance in order to make the other two angles approximately equal.

The location on the baseline of hubs which are to be used to establish reference points for locating river-piers must be made with the use of these hubs in mind. Instrument points and foresight targets must be high enough to look over construction equipment until the foresight can be transferred to the face of the pier nearest the instrument. Confer with the contractor before deciding where these important hubs will be set. They must be used until shoe centers are scribed on the pier top.

Where triangulation is used to locate otherwise inacessible piers during construction, the base lines should be located so the three lines should <u>intersect</u> at the pier center. Thus, any error in any one line will result in the formation of a triangle within which the true point lies. See Figure 3.

In reading the angles, the closure of the three angles of a triangle and the adjustment of them should be sufficiently accurate to keep the possible errors in the computed cross-river distance in any one triangle less than 0.04'. Obviously, this requires closer work if the cross-river distance is 1,000 feet than if it is only 200 feet.

For the 1,000 foot distance, a maximum error of 4" in closure should be required, whereas for the 200 foot distance, an error in closure of 20" would be satisfactory. If the computed distances from the two triangles were off in the same direction, the distance used would be wrong by the 0.04' mentioned above. If the computed distances were wrong in different directions, they would partially balance and result in a more accurate distance. Any transit which is in good adjustment can produce this degree of accuracy if the angles are repeated enough times in each set of readings. Obviously, a transit reading to 20" will require smaller sets than one reading only to 1'. Textbooks on surveying go into detail about the mechanics of such angle measuring and should be consulted by the instrumentman.

The measurement of the baselines should be made with steel tapes having the graduations etched on the tape (line), itself, and having the graduations begin and end several inches from the end of the line. The foot before the zero should be divided to hundredths. Such a tape should be a new one, or an old one which is in good condition, and which has been recently compared with the D-5 standard tape. The comparison is made as follows:

1. A flat floor more than 105 feet long is used and both tapes are stretched side by side on the floor to assume the same temperature. The floor may be of any material as long as it is smooth and flat. Temperature is disregarded in this comparison by having both tapes the same temperature.
2. Paper stickers are fastened to the floor at points corresponding to the 0, 25, 50, 75, and 100-foot marks on the standard tape. A starting line is marked at the zero end.
3. The standard tape is then used, under a 10-pound tension, to mark the correct distances on the 25, 50, 75, and 100-foot papers.
4. The tape which is to be compared will then be immediately placed in position and put under standard tension. This is 10 pounds for tapes 100 feet or less in length and is 20 pounds for tapes over 100 feet in length. The corrections, if any, at each tape interval will be noted.
5. If the correction can be eliminated by using a tension different from the standard, that tension will be determined.

With this information the tape can be used for exact measurements, <u>when it is fully supported</u>.

As baseline measurements must be made under conditions where the tape cannot be fully supported, it is logical to decide, while the comparison is being made, what interval of support will be used in the field and determine what tape tension is required to give correct lengths with those intervals. Twenty feet is suggested and, following Step 5 above, the tape can be blocked about 2" above the floor at those intervals and checked immediately. About two pounds additional tension may be required, depending on the weight of the tape.

In the field, nails driven into the side of stakes provide good, frictionless support and should be set at the same elevation to have the tape level between chaining hubs. Where irregular ground is encountered, chaining may be done on the slope with correction for slope distances applied.

Terminal hubs in baselines will have tack points. Intermediate hubs used for chaining should not have tacks in them but a knife blade or a scribed mark on an aluminum or copper plate is preferably used and varied in location for each complete measurement of the baseline.

When measuring the line, a series of about four readings, with temperature recorded, is recommended between each pair of chaining hubs before moving to the next pair. Throw out wild readings and wind up with three or four readings in a close group. Use the average of this group both for tape reading and for temperature. Correct for temperature variation from 70°F.

Layout work, preparatory to actual measuring of the baseline, can be done in any condition of sun or wind. The actual measuring is best done when there is little wind and under conditions where tape temperature can be closely known. This condition is best found when the sun is not shining, whether before sunrise or on a cloudy day. If the tape is supported on nails driven in the sides of stakes, and if weather conditions are favorable, a small thermometer hung on a stake near tape level will give satisfactory results.

In case piers cannot be located by direct measurement from hubs on dry land, the baseline layout is used to locate them by intersection of three lines. See Figure 2. Here, the center pier of a four-span plate girder unit is located in deep water where the contractor will use floating equipment and build a cofferdam.

The cross-river distance AB has been determined from triangles ABC and ABD, of which AC and AD are baselines. Angles A1 and A2 were measured at this time. While these baselines were being measured, hubs E and F were also accurately located for use in locating pier P at station 104+00.00. The hub at A is at station 101+94.00,; hence the distance AP is 206.000'. With two sides and the included angle, we solve for angle E in triangle AEP and for angle F in triangle AFP. The next step is to establish foresights EE and FF on the side of the stream opposite E and F. (See later comment about solving for these angles.)

To establish EE, point E is occupied, the angle E is turned once, as close as the instrument can be read, and a tack point is set at ee. A rod is then set on ee and the angle AEee is measured by repetition to the required accuracy. It will not be exactly the required angle E which was computed and must be corrected as follows. The distance E-ee can be scaled from the map or read by stadia. Compute the offset to be made at ee to correct the discrepancy mentioned above and make it. Occupy this offset point, backsight on E, plunge and set EE. Repeat this performance to establish FF.

Now when the contractor gets his cofferdam built for pier P, the exact point can be established for the pier centerline in the manner shown in Figure 3.

C. Types of Construction Stakes Usually Set

1. Excavation Stakes

The elevations of the ground surface over the area to be excavated for any substructure footing must be secured before any excavation is started. This must be done in order to calculate the quantity of structural excavation performed by the Contractor. The specifications provide that yardage of structural excavation normally is measured in its original position by the crossection method. The Engineer, therefore, must be sure that sufficient elevations over the area are secured to furnish complete measurements by this method.

2. Caissons and Cofferdams

The location and sinking of caissons requires that the axis of the caissons be located by construction stakes which must be available for use at all times. The axis of the caisson should be marked prominently on the top of the caisson wall so that the location of the unit may be checked either by stringline, blumb bobs, or by instruments, whichever is desired. The same type of control or staking applies to cofferdams.

3. Piling Stakes

The minimum number of construction stakes required to locate a trestle piling bent should locate the transverse centerline of the bent as well as the longitudinal axis of the structure. Each individual pile location may also be staked.

4. Pier Footing Stakes

The minimum number of stakes necessary for the location and construction of pier or bent footings should locate the two axis of the footings in a manner that will permit direct measurement from the stakes to delineate the size of the excavation. Where deep footings are involved, it may be necessary to reset stakes or points in the bottom of the excavation for convenience in locating the forms and dowel bars. If the Contractor is using timber or steel cofferdams, these points may be transferred to the lower walers or braces for use in fine grading the footing and locating the forms for dowels.

5. <u>Additional Stakes</u>

It is emphasized that the above recommendations cover only the minimum number of stakes which are considered necessary for the location and construction of the various structure units. A competent bridge foreman using these stakes can locate the necessary offset stakes that he desires to maintain control of the construction and to complete the structure in accordance with the lines and grades shown on the plans. Additional stakes may be set as desired to expedite the work and simplify the operation of checking the Contractor's work.

The Contractor is responsible for the reasonable preservation of the construction stakes, but it must be recognized that complete preservation of all construction is not always practicable. It is necessary, therefore, that the Engineer be prepared to reset construction stakes as the work proceeds.

D. Horizontal and Vertical Control

1. Pier and Bent Control

Where piers or bents extend any appreciable height, the Engineer should establish horizontal control of the forms by means of reference hubs. These hubs should be placed in a manner that will permit the direct transfer of centerlines (transverse and longitudinal) from the ground to the top of the units by transit sights. Where these units are of considerable height, it will be necessary to establish reference hubs in a series on each side of the unit. These hubs will provide a transit point and backsight far enough away from the structure to permit proper setting of the centerlines on the pier or bent tops.

2. Curb and Railing Control

The curb and railing lines on any structure may be considered critical lines in that they are the lines observed by the largest majority of people. These lines should be controlled by instrument at all times in order to secure the most satisfactory result. Control stations for the alignment of the curb and railing should be established beyond the limits of the construction operation on both ends of the structure and on both curb lines. Semipermanent backsights should be placed on each line. The targets on these backsights should be checked for location at frequent intervals because of the possibility of disturbance by spectators, laborers, or construction equipment.

3. Control Stations on Structures

In cases where the topography will not afford a suitable location for control stations beyond the limits of the structure, it may be necessary to construct stations on the structure. If the curb is not wide enough to permit proper instrument setups, a platform should be constructed for this purpose which will provide a substantial base for the tripod and independent support for the instrumentman.

4. Construction Bench Marks on Structures.

It is generally convenient to establish construction bench marks on the completed portions of the structure for temporary use. When such bench marks are established, they should be carefully protected and marked. These bench marks must not be established on any portion of the structure which will be changed by rubbing operations after the elevation has been established.

Construction bench marks on structures must be checked from the permanent bench marks off the structure at frequent intervals to verify the stability of the unit on which they are placed.

E. Staking Records

1. General

The necessity for accurate records of the stakes and grades set should be apparent to any engineer. Uniformity in these records is required because they may be used by several men during the progress of the work. The following general rules should be observed in keeping construction notebooks and other records:

(1) The pages of all notebooks should be numbered.

(2) An index of the contents of the book should appear on the first page.

(3) Sufficient notations should appear on the first page of each sequence of notes to show precisely the nature

of the work. It is recommended that notes made and later discarded or not used should be crossed out in order that a stranger would understand readily that they had been abandoned. However, they should not be erased under any condition. Notations as to what each column in the level book represents must also be made on the first page of each sequence of notes.

(4) The date and name of each member of the field party should be shown at the top of the first page of each day's work and also a notation about the weather conditions.

(5) Notebooks on structures, pavement, etc., should contain all sketches, measurements, and calculations necessary to show the quantities and dimensions of the work performed.

The following are items which generally appear in the staking records of a bridge job:

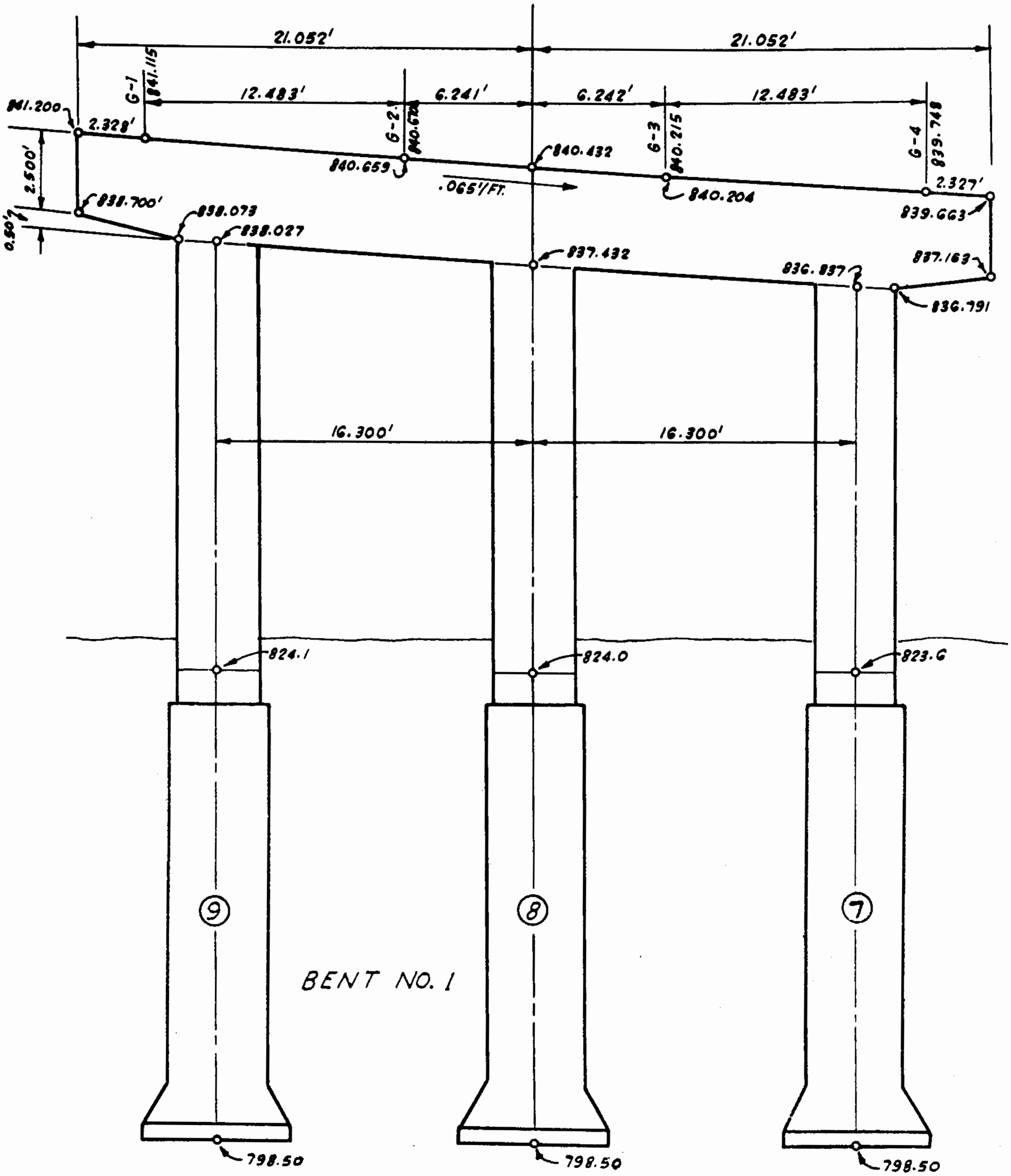
(1) A general layout.

(2) A bent layout.

(3) A layout showing the bearing seat elevation and distance for each stringer or beam.

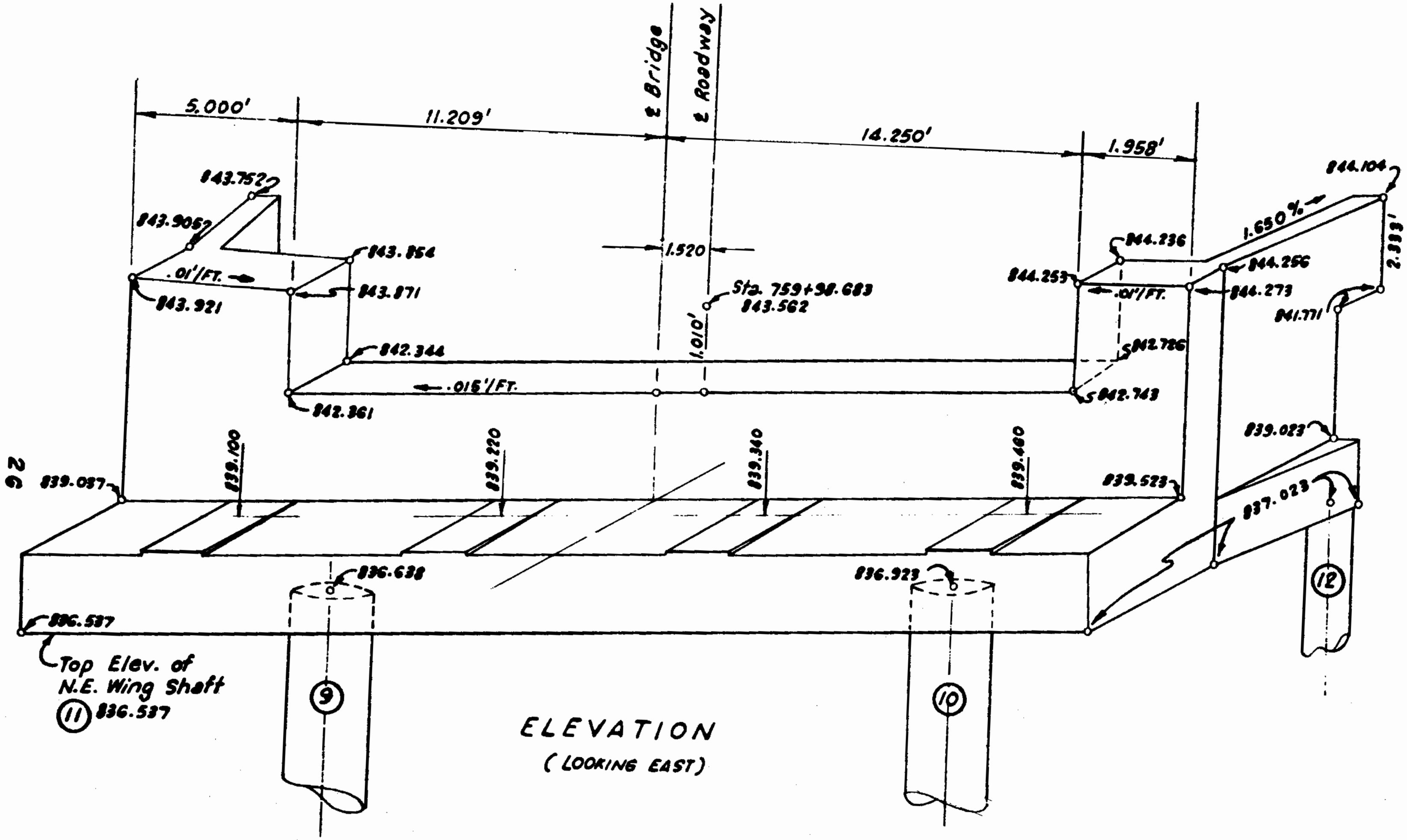
(4) A deck layout of all grades for the control point needed to establish the finish of the top of slab elevation.

(5) Centerline curb data and the curb deflections.



21.052'
21.052'
12.483'
6.241'
6.242'
12.483'
G-1
841.115
G-2
G-3
840.215
G-4
839.748
841.200
2.328'
2.327'
2.500'
0.50'
840.659
840.432
840.204
.065'/FT.
839.663
838.700'
838.073
838.027
837.432
836.837
837.163
836.791
16.300'
16.300'
824.1
824.0
823.6
9
8
7
BENT NO. 1
798.50
798.50
798.50

FIG. 4 A



ELEVATION
(LOOKING EAST)

ABUTMENT 2
STRUCTURE 'A'
U-1075 (9)
2-27-57

FIG. 4 B

It is important that each notebook be numbered for identification purposes. The name of the county, the highway number, project number, and the control number should be placed on the back of the field book.

2. Examples of Records

As construction proceeds, all field data pertaining to the particular structure should be entered in the pages of the field book previously established for such information. This information should completely establish bench marks, rod readings, grade points, cuts and fills for bearing seats and slab, etc. Since abutment bents are more involved, separate sketches should be made showing all elevations required for actual construction. Figure 4-A shows all the elevations usually required for bent construction. Figure 4-B shows a perspective of an abutment bent showing the essential grades computed at each point for the abutment bent. All of these grades should be computed and checked to eliminate guesswork and to provide the refinement which is considered necessary for a well-constructed bridge.

If both abutments are the same, this sketch can be made on tracing paper, then by turning the tracing over and running it through a printing machine, the print for the second abutment may be obtained. Then, the required elevations may be put on the print.

II. Piling

A. General

1. Introduction

Piling have been used by mankind for centuries as a method of supporting footings and foundations for structures that were too heavy to rest on the natural soil, or they have been used to raise structures out of the water or away from the ground. Piling are still being used for the same purposes today, but more knowledge has been gained concerning the properties of these structural units. There is still room for increased knowledge in the piling field, as there is in every field. The data presented herein will reflect good construction methods and practice.

The objectives to be attained in pile placement are:

(1) Driving the piling until it is capable of carrying a superimposed load.

(2) Getting the piling far enough in the ground to be reasonably secure from scour and lateral displacement, in other words, to secure bearing and penetration.

2. Specification Requirements

a. Driving Equipment

Item 404.5, page 389, of the Standard Specifications gives the detailed requirements for the driving of piling for structures. The following notations are brief summaries of the major items carried in this specification. Each person involved in driving piling should be thoroughly familiar with Item 404.

There are three types of pile driving hammers used at the present time on highway structures.

They are:

(1) Single-action or double-action hammers which may be operated with either steam or air.

(2) Single-action diesel hammers which operate on diesel fuel or kerosene and double-action diesel hammers which have the ram enclosed in a compression chamber.

(3) Gravity Hammers

These hammers are used on fabricated leads either made by the manufacturer of the hammers or by the Contractor driving the piling. There are two types of piling leads in general use. They are either swinging or fixed leads. The fixed leads are those which are attached to the boom of the dragline. The swinging leads are attached to the boom of the dragline by cable.

The specifications state that the pile driver shall be equipped with leads which are constructed in such a manner as to afford freedom of movement of the hammer and which will provide adequate support during driving. The vertical axis of the leads and hammer shall coincide with the vertical axis of the pile. In order to accomplish this with a swinging lead, it is necessary to provide alignment holes and rigid templates that will hold the piling in the proper position. Piling driven in this manner are usually placed in the alignment hole with the templates holding the piling in position. The swinging lead is then placed on top of the piling and adjusted to sit vertically on the pile while it is being driven. The leads are usually blocked with timbers when this method is used in order to maintain the leads in an aligned position over the pile.

When fixed leads are used, the piling is placed in the leads along with the hammer and then positioned in its proper place in the footing or bent and the leads adjusted until they are aligned and the piling is in its correct position before pile driving begins.

The specifications permit driving of piling with gravity hammers when shown on the plans. Gravity hammers are usually used only to drive timber piling. A table showing the size of hammer to be used for different types of piling is shown on page 390 of the Standard Specifications. The Contractor should comply with the rating set out in this table for the size of the piling and the bearing that is required.

The specifications also state that where piling are driven through water, leads shall be of sufficient length that a follower will not be necessary. Where a follower is required for the driving of piling under water, one piling in each ten shall be of sufficient length that a follower is not required. This piling shall be driven as a test piling for proper correlation of the follower-driven piling in the group. These followers are usually made by the Contractor and are usually made out of H-beam or pipe piling of sufficient length to keep the driving head of the hammer above water.

b. Penetration

The minimum length of piling for stability of a structure is considered to be approximately twenty feet. Piling shorter than this are not ordinarily specified. The length of piling shown on the bridge layout is estimated to give the required bearing at the elevation shown on the plans. This is not necessarily the depth that will be needed for required bearing. In some instances, the depth specified is greater than is needed to obtain the required bearing. Specifications state that the elevation shown on the plans is the minimum depth to which the pile should be driven unless the driving is near refusal and sufficient penetration has been obtained. Piling shall be driven to this depth or to such greater depths required to obtain the specified bearing resistance. Sometimes, the upper strata that the piling goes through is of water or muck or other similar unstable material, and it is often necessary to drive the piling deeper than the point which we obtained the required bearing from the hammer formula.

Sometimes, the piling cannot be driven to plan penetration by the driving hammer alone. When the specified penetration cannot be obtained by driving without damage to the piling, the Contractor shall provide either pilot holes or jetting equipment or a combination of both.

(1) Pilot Holes

For soil material which will not permit efficient jetting operations and in which the piling are to penetrate a hard or firm material which cannot be penetrated by ordinary driving, the Contractor shall use pilot holes in order that the piling may be placed to the depth required and driven to a specified resistance.

The pilot holes shall generally have a diameter of approximately four inches less than the diagonal of square or steel H-piling, two inches less than the diagonal of octagonal piling and one inch less than the diameter of round piling. (See Item 404.7, page 392, of the Standard Specifications) These holes shall be made to such depth as necessary to secure the penetration shown on the plans. Where pilot holes are required in material which consists of loose sand or gravel overlying a hard clay or shell which cannot be sealed off by ordinary mudding drilling methods, the following method shall be used.

A casing pipe of sufficient diameter shall be placed around the boring device in a sufficient length to extend down through the upper strata of loose materials to the firm material. This casing must be held in position until the pilot holes are completed and the piling has been driven a sufficient depth through the clay material to prevent sand and other loose material from dropping into the pilot hole. Then the casing may be removed by the Contractor.

The Contractor should never be allowed to drill all of his alignment or pilot holes and place the piling in all of the holes before he starts driving operations. This has happened in instances when the Contractor could not get the piling to grade because the piling would reach refusal when calculated by using the hammer formula. The Contractor should have tried several different depths of alignment or pilot holes so that the necessary size and depth of pilot holes to get to plan grade could be determined at the outset of the pile-driving operations. In the case mentioned, it was necessary for the Contractor to drill relief holes down beside each piling to obtain the required penetration of the piling and also to get the required bearing. This was accomplished by drilling six-inch shafts down two sides of the piling which relieved the pressure sufficiently to allow the piling to be driven to grade.

(2) Jetting

In localities where water is available and the material is suitable for jetting, such as sand or gravel, a mixture of both, or a mixture of sand and clay, the Contractor may provide jetting equipment as an auxiliary to the steam hammer as a means of placing the piling.

For jetting operations, sufficient power shall be provided to operate one or more pumps and a minimum of two $2\frac{1}{2}$-inch diameter jets provided with three-fourths-inch diameter nozzles.

The plant shall be such that with two jets operating at the same time, it shall deliver a minimum of 150 psi pressure at each nozzle. The jetting operation may be done with the use of one or two jets as determined by the Contractor and approved by the Engineer from the results of trial jetting operations. If water jets in combination with a hammer are used for driving the piling, the jets shall be withdrawn and the piling shall be driven by the hammer to secure the final penetration.

When piling are being driven inside a cofferdam and it is necessary to resort to jetting to obtain the required penetration, the best results are obtained using hollow piling. With the hollow piling, the Contractor can insert his jetting equipment inside the hole and jet the material out the top of the pile. This method of operation eliminates the possibility of a blow-in in the cofferdam if the tip of the piling is not sufficiently below the bottom of the river, lake, or bay. (Item 404.8, page 393, of the Standard Specifications)

c. <u>Bearing</u>

The bearing resistance of all piling is determined by various formulas which are given in the Standard Specifications. (Item 404.9, page 393, of the Standard Specifications)

d. <u>Alignment</u>

The alignment of piling in a structure is a very vital part of the construction. Item 404.3 gives the tolerances that are allowed in the driving of trestle bent piling. This item states that:

(1) In the direction of the longitudinal centerline of the structure, the top of the completed piling shall not be more than two inches from the position as shown on the plans.

(2) In the direction along the transverse centerline of the bent, the top of the completed piling shall not be more than four inches from the position shown on the plans.

This tolerance is intended to be the allowable tolerance after the piling are driven, and in no case, should the Contractor be permitted to start driving the piling in a position to use up this tolerance when he starts his initial driving. The piling should always be placed as near the exact position that it will occupy in the structure as possible, held in that position by templates or fixed leads in combination with alignment holes. After the piling has penetrated the substrata for a good portion of the length of the piling, the application of force by moving the leads to try to hold the pile in position should not be resorted to. The only case where the piling should be out of alignment at this time is where the piling encounters a sloping strata, a tree trunk, or some other object that causes the tip of the piling to try to move from its original direction and position. In those cases, the piling should be allowed to walk in the direction it is moving, and after the driving is completed, the piling that is not within the specification tolerance may be moved into position by drilling holes down alongside the pile and driving wedges and applying force at the ground line to the pile to move it slowly into position. Cables and struts should never be tied to the top of a pile to try to pull it into position as in all probability this will crack the piling. Along the same line, the piling should never be driven while being restrained or the leads should never be moved while driving is going on.

Foundation piling do not have the same tolerance that trestle piling have. It is necessary, however, that they be driven to the vertical or batter line indicated and the top of the completed pile should not be more than four inches in any direction from the position shown on the plans. The center of gravity of the pile group should be determined for each footing, and if that center varies by more than three inches from plan location, a structural analysis should be resorted to to determine what additional measures will be required to meet minimum standards. The minimum concrete cover for piling in footings shall be five inches and the pile shall be in such a position to permit proper placement and cover of reinforcing steel. If it is not possible to do this, then a structural analysis should be resorted to and in all probability, a larger footing will have to be installed.

Inspection Tips

A plumb bob with string attached is a very good piece of equipment to be used during pile driving operations. Plumb bobs are used to help plumb the piling after they are positioned over the stakes locating the exact spot in the trestle or footing that the piling is to be driven. Normally, a transit is used for the alignment along the transverse centerline of the bent and the plumb bob may be used to plumb the piling along the longitudinal centerline of the structure. In checking the alignment with a transit, the transit should be set up a specified distance offset from the centerline of the bent. In this manner, the instrumentman and the inspector may hold a rule on one face of the piling to check its location and its direction. In a transverse direction, the position of each pile may be checked by measuring from the base of one pile to the other and adding the thickness of the piling. This should give the center-to-center distance as shown on the plans. Normally, each piling is staked, but after the piling has started to be driven, it is necessary to check the position for the first few feet of penetration. The Contractor will normally use a long carpenter's level to check the piling as it is being driven. Normally, in trestle bent piling, one is driven after the other. When this procedure is used, the position of the next bent should always be checked from the preceding bent. It is not desirable to assume that the stake for the next bent is in the correct position. The distance should be measured back to the preceding bent to see that the span is correct.

To get trestle bent piling to the desired penetration, it is usually desirable to set up a level and predetermine the HI of the instrument. Having predetermined the HI of the instrument and by knowing the top of the pile elevation, the stopping point may be marked on the piling by marking down from the top of the pile a distance equal to the top of pile elevation minus the HI elevation. (When HI is lower than top of pile) The break back point for the bottom of cap elevation can be marked on the piling at this same time. This will have to be done before the piling is picked up and put in the leads. This procedure will eliminate the need to come back and locate the bottom cap forms for the caps if pile is driven accurately to grade.

The plan grade for footing piling may be determined in much the same manner as trestle bent piling. It is usually necessary, however, to stop driving the foundation pile a few feet before the pile reaches plan grade. Then, measurements are made to determine just exactly how much above plan grade the top of the pile is. From this, it can easily be calculated how much further into the ground the piling must be driven. Match marks can be placed on the leads or other portions of the equipment to enable the instrumentman to stop the pile within close tolerances of grade. The penetration blows per inch may also be recorded at this time, and when the cut-off grade is reached, the instrumentman can stop the driving. This is the safest method of determining the bearing of the piling and also to get the piling to plan grade. Other methods that are used are more dangerous, and this method should be used whenever possible.

The length of stroke for single-acting hammers, (diesels, steam, or air-operated hammers), should be determined as accurately as possible. For diesel hammers, it will be necessary to measure down to the top of the piston when the piledriver leads are in position on top of the pile and determine the distance to the top of the hammer. A colored red and white rod may then be positioned on the outside of the hammer and these marks should be in six-inch increments. The first mark should be positioned to place an even foot mark exactly above the top of the ram at rest. The length of the stroke for single-acting steam hammers should also be measured and not taken from the manufacturer's catalog. This measurement should be checked immediately before taking penetration data, and the Contractor should not be allowed to throw in an additional cushioning material after this measurement has been made. If the hammer is not operated at a uniform rate of speed and sufficient steam pressure, the ram will not assume a full stroke.

B. Timber Piles - Special Instructions

1. Inspection, Storage and Handling

Item 406 of the Standard Specifications provides a detailed description of the various kinds of timber piling which may be used.

The schedule of minimum requirements provides that inspection shall be made on all piling at the point of origin. This applies to both treated and untreated material. This does not relieve the Resident Engineer of any responsibility with regard to the acceptance of such material. If it is apparent that this material does not conform to the specifications after it has been delivered to the work, the material may be rejected at any time prior to final acceptance of the structure. Item 406 gives detailed requirements regarding the standards that the timber piling must meet.

Untreated timber piling must be open stacked if injury to the piling is to be avoided. It shall be stored on skids or blocks above the ground and each tier or layer of piling shall be separated from the one below. This is necessary to avoid the development of rot and decay which may be very rapid in warm damp areas if proper circulation of air is not maintained around each piling. Treated timber piling may be close stacked.

All piling in storage should be supported sufficiently throughout their full length to prevent warping and bending. Unless such precautions are taken, piling which were acceptable when delivered may assume shapes beyond tolerances permitted by the specifications and be very difficult to drive in proper alignment.

Treated timber piling should be carefully handled and sudden drops or breaking of the outer fibers, bruising or penetrating the surface with tools should be avoided. Timber piling should be handled with rope slings and should not be handled with cant hooks or pike poles.

2. <u>Driving</u>

Timber piles can be easily injured in driving and particular care must be taken to avoid serious damage. This is particularly true when hard driving conditions are encountered or where very heavy hammers are used. Caution must be taken to prevent splitting or excessive brooming of the pile end. The head of the piling should be cut off square and smooth so that the force of the hammer blow will be distributed evenly over the entire top surface. The weight of the hammer and the hammer speed should be so regulated as to avoid material damage to the top of the pile.

Where hard driving conditions are encountered, caps and cushion blocks should always be used. When these items do not eliminate damage to the pile heads, the Contractor should be required to find other methods to drive the piling in order to prevent excessive damage. The specifications state that broken, split or misplaced piling shall be withdrawn and properly replaced on directions as specified by the Engineer.

No definite statement can be made to cover all circumstances that might require pointing of piling. In general, piling should be pointed when the nature of the foundation material is such that packing under the pile tip may be reduced by wedging aside this material to secure additional penetration without damage. Piling should never be pointed when they are used to penetrate hard stratified material as such pointing will only result in crushing of the pile tip and loss of the equivalent penetration. Alignment control is very difficult when piling are improperly pointed.

C. Concrete Piles - Special Instructions

1. General

Particular care must be observed in the handling of concrete piles when they are moved from the storage pile to the pile driver leads to avoid cracking or actual breaking the pile. Most reinforced concrete piles are not capable of carrying their own weight with safety when supported only at the extreme end as is the case when a pile is lifted by means of a single cable attached to the end of the pile. The concrete piling should be handled by means of a bridle or sling attached to the pickup points as indicated on the plans. The specifications do not permit the use of chain slings in handling the piling.

2. Inspection

Piling cracked in the process of curing and driving, whether or not limiting stresses have been exceeded, shall be subject to the following provisions.

(1) Any piling which is cracked to the extent that the crack shows severe spalling to indicate that reinforcing has been permanently disabled shall be rejected if the cracks occur in a portion of the pile which will be below the ground when the piling is driven.

(2) Piling cracked as described in (1) and on which the crack occurs in a portion of the pile which is not below ground when the pile driving is completed may be used in the structure provided the Contractor will, at his own expense, cut the concrete of the pile back to the crack and then treat the pile as a build-up.

(3) Piling which have cracks that show spalling,and which cracks are closed to indicate no permanent distortion of the steel has occured, may be used if the Contractor will, at his own expense, waterproof the area over the crack with an approved epoxy waterproofing material. For cracks one-thirty-secondths-inch in width or greater,

the crack shall have a vee formed one-eighths-inch in width and in depth so that the epoxy waterproofing will have depth and width over the crack.

The waterproofing shall be applied over the crack and an area at least one inch each way from the crack. If, in the process of pile driving, cracks develop in the portion of the pile which will be below ground, the driving operations shall be stopped for a sufficient length of time to permit the required waterproofing to be done before the crack enters the ground.

(4) Fine hair cracks or checks on the surface of the pile which, as determined by the Engineer, do not extend to the plane of the nearest reinforcing steel, will not be cause for extra treatment or for rejection of piling under these specifications, except that piling may be rejected if such cracks are numerous and extensive enough that inadequate curing is apparent.

(5) If any prestressing tendon or portion thereof is broken prior to placing of concrete, it shall be replaced with a satisfactory unit properly prestressed. The breaking of one wire of a seven-wire strand during concrete placing operations will be subject to a structural review prior to acceptance.

(6) All replacements or repairs as herein specified as well as all other replacements due to faulty materials or construction methods shall be made at the Contractor's expense.

3. Protection during Driving

A structural steel driving head suitable for the type and size of piling being driven shall be used. Wood cushion blocks shall be used if necessary to prevent damage to the pile. For concrete piling, either precast or prestressed, cushion blocks shall be provided for the top of the pile. These blocks shall be at least four inches in thickness, made of a material which will not crush to such an extent that cushioning effect is lost. Green oak or similar material is usually satisfactory. Cushion blocks should be changed as often as necessary to prevent damage to the pile. This is particularly true in the case of prestressed concrete piling. For prestressed concrete piling, it is extremely important that the tendons protruding out of the top of the pile should be recessed and that the top of the pile head be level and square. It is oftentimes necessary to change cushion blocks on every pile that is driven where prestressed concrete piling are being used in order to prevent cracking and spalling of the piling during driving. The specifications state that cushion blocks shall be changed as necessary to prevent damage to the pile, and the Inspector should see that the Contractor complies with this necessary part of the specifications.

Any piling cracked or spalled due to the reluctance of the Contractor to change cushion blocks will necessarily require that additional work will be required in providing a suitable supporting element of the structure and will be at the Contractor's expense. Other methods of providing a satisfactory pile may be used in lieu of cutting back the piling to grade and building it up to the required height. A reinforced concrete collar has been used around the cracks for a sufficient distance in either direction to transmit the necessary strength to overcome the defect to the pile.

Where long reinforced or prestressed concrete piling are to be driven on a batter, it will usually be necessary for the Contractor to provide some method of support along the back of the piling while it is being driven in order to overcome any breaking or cracking of the piling due to the unsupported length. The requirements for pickup should be satisfied in this instance the same as for handling.

During driving of concrete piling, it is essential that the cushion and driving block be in such a condition that the force of the hammer blow is evenly distributed over the end surface of the pile. In other words, the pile head and cap should be level. If this condition does not exist, then one side of the pile will take the full force of the hammer blow causing cracking and spalling of the head. Any damage resulting to the top of the head of the piling will be repaired at the Contractor's expense.

In making cutoffs, care should be taken to avoid cracking the concrete below the point of cutoff. Cutoff lines should be carefully marked around the circumference of the pile and a deep groove chiseled completely around the pile at this point. The groove should be of sufficient depth to expose the main reinforcing steel or prestressing wire which then can be cut into with a hacksaw or cutting saw. After the steel is cut, the pile can be broken off with a sledge or other means. If the concrete is cracked below cutoff grade in attempting to make the cutoff, all of the concrete must be cut out at the bottom of the cracked portion and built back up to correct grade at the Contractor's expense. Details covering concrete splices are shown on the plans for each type of concrete piling. It is to be noted, however, that where a prestressed concrete pile is built up and has to be driven after making the buildup, that this concrete shall be Class "F" concrete.

The general use and treatment of steel piling follows closely the practice used for concrete and timber piling. It is generally accepted that steel piling are capable of being driven in hard material where timber or concrete piling would require pilot holes.

2. Driving

Whenever hard driving is encountered with this type of piling, the Contractor should be required to secure a structural steel or cast steel driving cap fitted with wood cushion blocks to protect the head of the pile. This cap should be grooved to fit the flanges and preferably the web of the pile.

Cushioning should be sufficient to prevent material damage to the pile head under driving. Under ordinary conditions, it is safe to assume that if driving conditions are not serious enough to damage the portion of the pile above ground, that portion under the ground is not being damaged materially. If the head of the pile is badly crimped or otherwise damaged during driving, this portion would have to be cut off and replaced by splicing on an undamaged section of suitable length at the Contractor's expense. All splices are to be made by butt welding in accordance with the details shown on the standard plans.

Where pile heads are required by the plans, the end surfaces of the piling shall be made as smooth as practicable for the pile head to be welded in place. Pile heads shall conform to the plan details. If the piling do not require a head, then the piling shall be cut off level with a cutting torch or other acceptable methods to plan grade or the grade established by the Engineer. Steel bearing piles ordinarily do not pass through the hands of a fabricator or an inspection agency before they arrive on the job. It is therefore the responsibility of the Resident Engineer or his Inspector to check the piling to see that they conform to the correct size and any visible defects that might be noted. Also, it should be noted that the piling should be positioned as shown on the bridge layout or footings when they are driven. In other words, these piling have two different section modulus along the "X" and "Y" axis and it is important that they be placed in the position as shown on the plans.

III. <u>Cofferdams, Underwater Seals and Footings</u>

A. <u>Cofferdams</u>

1. <u>General</u>

The term, cofferdam, designates any temporary or removable structure which is constructed to hold surrounding earth or water, or both, out of an excavation. These structures may be formed of earth, timber, steel, concrete, or a combination of these materials, including earthen dikes, timber cribs, any type of sheet piling, removable steel shells and the like. The term "cofferdam" should also be understood to include the use of pumping wells or well points for the same purpose. The cost of cofferdams is always included as part of the bid price for excavation. Where there is no provision for a cofferdam shown on the plan, it is the intent of the specifications to require that a suitable cofferdam be provided for all excavation necessary. If no ground water or surface water is encountered, the cofferdam must be sufficient to protect the workmen from cave-ins or slides.

The Contractor shall submit drawings to show the proposed method of cofferdam construction. The type, strength and clearance of cofferdams will be subject to approval of the Engineer. Other details of the design will be left to the choice of the Contractor who will be responsible for the successful completion of the work. Approval of the drawings by the Engineer will not relieve the Contractor of any responsibility in this matter. The interior dimensions of the cofferdam shall give sufficient clearance for the construction and removal of required forms, inspection of the exterior of forms and to permit pumping outside the forms.

2. <u>Steel Sheet Piling Cofferdams</u>.

In general, steel sheet piling cofferdams shall extend well below the bottom of the footings and shall be as watertight as possible. Before the Contractor starts driving sheet piling for a particular cofferdam, a template the size of the cofferdam to be constructed should be positioned as close to the pier location as possible. This template should be aligned along the centerline of the bridge and transversely along the centerline of the pier. This template may be of wood or steel sections made into a rectangle supported on timber piles, H-beams, or metal shells. Usually, the template will be one of the interior supporting frames of the cofferdam.

After the template is positioned, the Contractor will then begin placing the sheet piling around the outer perimeter of the rectangle. Normally, all steel sheet piling is placed around the perimeter of the cofferdam before any piling is driven to grade. The sheet piles should be interlocked, one at a time and should be driven only a small distance to seat them into the substrata of the stream or bay. The Contractor should never drive the sheet piling to grade without proceeding around the perimeter of the cofferdam driving each section of the steel sheet piling a few feet at a time. In this manner, each section may be kept vertical, thus preventing the sections from unlocking during driving.

After sheet piling are driven to pre-established elevations above the normal elevation of the stream, bay, or lake, the Contractor will then start making preparations to place the interior bracing of the cofferdam. (The elevation at which the sheet piling should be stopped should always consider the possibility of flooding from high waters.) The Contractor should construct the interior bracing so that the low braces will have less perimeter than the upper sections in order that they may be lowered and positioned into the cofferdam. The interior braces should be lowered as the material is excavated from the interior of the cofferdam. This is extremely important, for if the Contractor excavates too far, the exterior pressures of the soil and the water may collapse the cofferdam enough that it will be impossible to set the interior bracing at the desired elevation. These interior braces or frames should be positioned so that one frame would be at the top of the proposed seal and another frame at approximately one third of the distance from bottom of the cofferdam to the top of the water.

The cross-braces of these frames should not interfere with the pouring of the columns or the web of the pier, itself. The bracing may have to be cut and welded to the frame at each corner while the web wall of the pier is poured. It should be remembered that, in all cases, these bracing members should be positioned so that the Contractor may have room to install forms and devices required.

In some instances, it is possible to de-water the cofferdam before the seal is placed. If this is possible, it is the preferred method because the excavation may be cut to an exact grade before the seal is poured. The condition usually will occur when the sheet piling penetrate into a firm strata of clay and there is not sufficient pressure or head of water on the outside of the cofferdam to cause the clay to blow in below the bottom of the sheet piling. If it is not practicable to de-water the cofferdam before the seal is poured, the bottom grade should be cut as closely as possible. The Contractor will usually remove enough material below the bottom of the seal so that during pile driving operations, the displacement of the material will not raise the grade above the tolerances permitted in the specifications. The specifications state that all foundation material that has risen to a level of more than one foot above the footing grade shall be removed. To make measurements under water, it will be necessary to use a pole of sufficient length to probe the bottom of the footing or to attach a weight to a metal tape and measure the elevation of the bottom of the footing in this manner. If a pole is used, it should have a flat piece attached to the bottom of it so that it will not penetrate into the muck at the bottom of the cofferdam. Sufficient checks should be made by either of these two methods to see that the footing elevation is within the established tolerance before the seal concrete is placed.

3. Timber Cofferdams

Timber cofferdams usually consist of sheet piling, known as wakefield sheet piling, either in single or double rows. If double rows are used, a clay puddle wall is usually placed between them. Special provisions should be made for adequate bracing of cofferdams for the protection of workmen in the work. It should be noted that in today's construction methods, the use of timber cofferdams has almost been completely relegated to the protection of excavation of earthwork and is very rarely, if ever, used in a condition where the sealing of either ground water or natural water is required. Timber cofferdams today are usually referred to as cribbing.

4. Concrete Cofferdams

Again, concrete cofferdams are seldom used, mainly because they are difficult to remove. (The cofferdam is not supposed to be a part of the permanent structure. A concrete cofferdam might be used where a sandy strata of water-bearing soil is found in a swift-running stream. It would be difficult to use another type of cofferdam in this case. The use of concrete cofferdams would usually be confined to the depth that would permit the base of the pier to be excavated either with or without a caisson. As a general rule, concrete cofferdams will rarely ever be used.

B. Underwater Seals

1. Placing Concrete

Item 420.14, Placing Concrete in Water, states that it will be deposited only when specified on the plans or with written permission of the Engineer. The forms, cofferdams, or caissons shall be sufficiently tight to prevent any water passing through the space in which the concrete is being deposited. Pumping will not be permitted while the concrete is being placed, nor until it has set for at least 36 hours. The concrete placed in or under water can be equally as sound and strong as concrete placed in the dry; however, special equipment and special procedures are required. The main idea in placing concrete under water is to have still water in the area where the concrete is being placed. The reason that pumping is not allowed while concrete is being placed nor until it has set for 36 hours is because hydrostatic pressure would try to force water through the concrete or between the concrete and wall of the cofferdam, thus creating voids or leaks.

Concrete placed in water should be carefully deposited in a mass by means of tremie, closed bottom dumping bucket, or any other approved method that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being deposited. Depositing shall be regulated to maintain an approximately horizontal surface at all times. This can be checked with a pole with a flat piece of board or metal attached. A tremie consists of a tube having a diameter of not more than ten inches, constructed in sections having water-tight connections. The top of this tube must always remain above water and it is usually fitted with a hopper to receive the concrete.

The means of supporting the tremie shall permit the moving of the discharge end over the entire top surface of the work and shall permit the tremie to be rapidly lowered when necessary to choke off or retard the flow. The number of times it is necessary to shift the location of the tremie shall be held to a minimum. During the placing of concrete, the tremie shall be kept full to the bottom of the hopper. The purpose of this is to give visual evidence that the charge has not been lost. Under conditions to be discussed later, this provision might be modified to permit flow of concrete at the lower end until the batch discharges to the level of the bottom of the hopper. The flow shall then be stopped by lowering the tremie. Placing operations shall be continuous until the work is complete.

When concrete is placed by means of a bottom dump bucket. the bucket shall have a capacity of not less than one-half cubic yard. These buckets are of special design and should be incapable of discharging until they are landed on the bottom or in concrete. The bucket shall be lowered gradually and carefully until it rests on the concrete already placed. A canvas cover to protect the surface of the concrete in the bucket

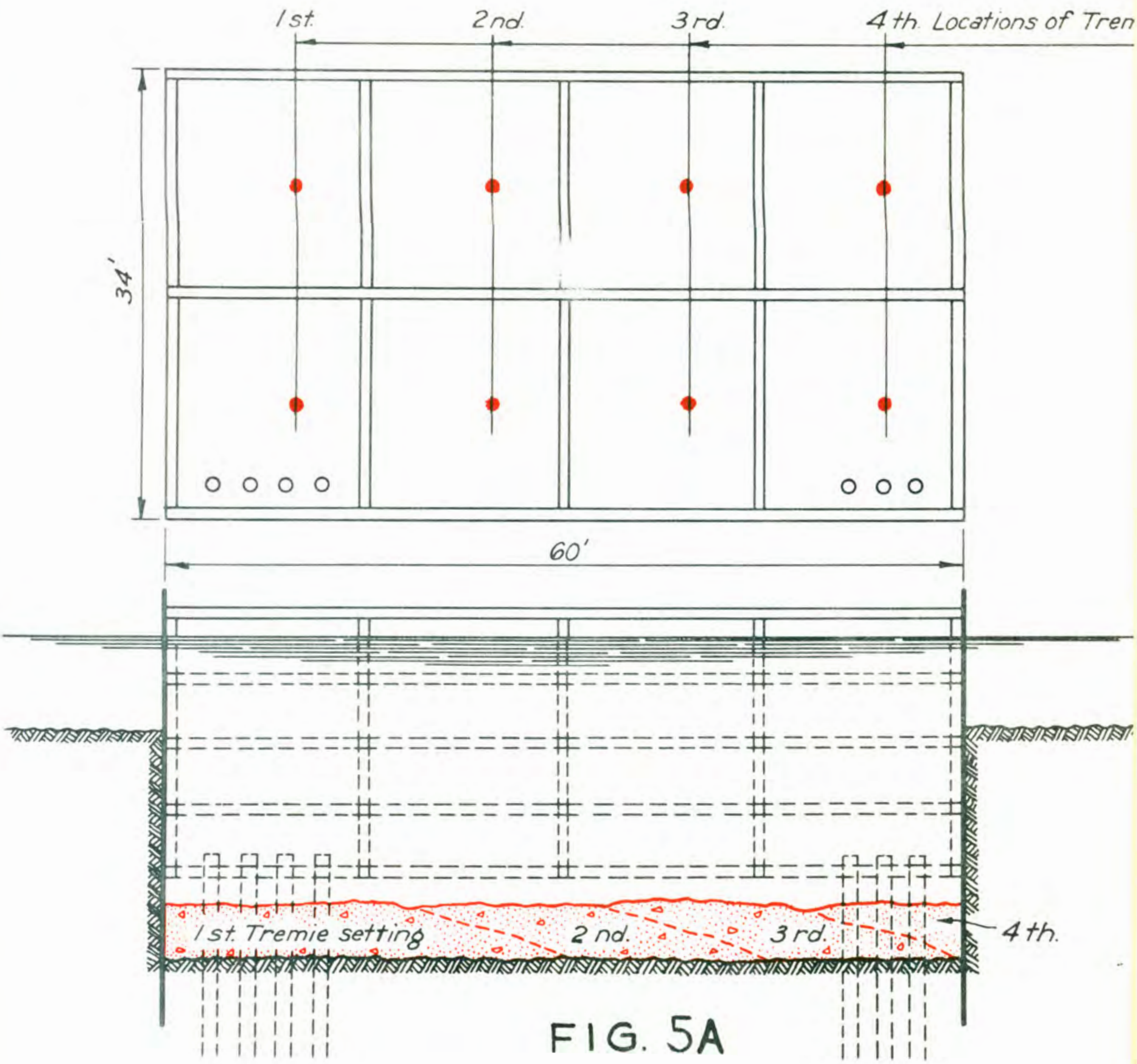
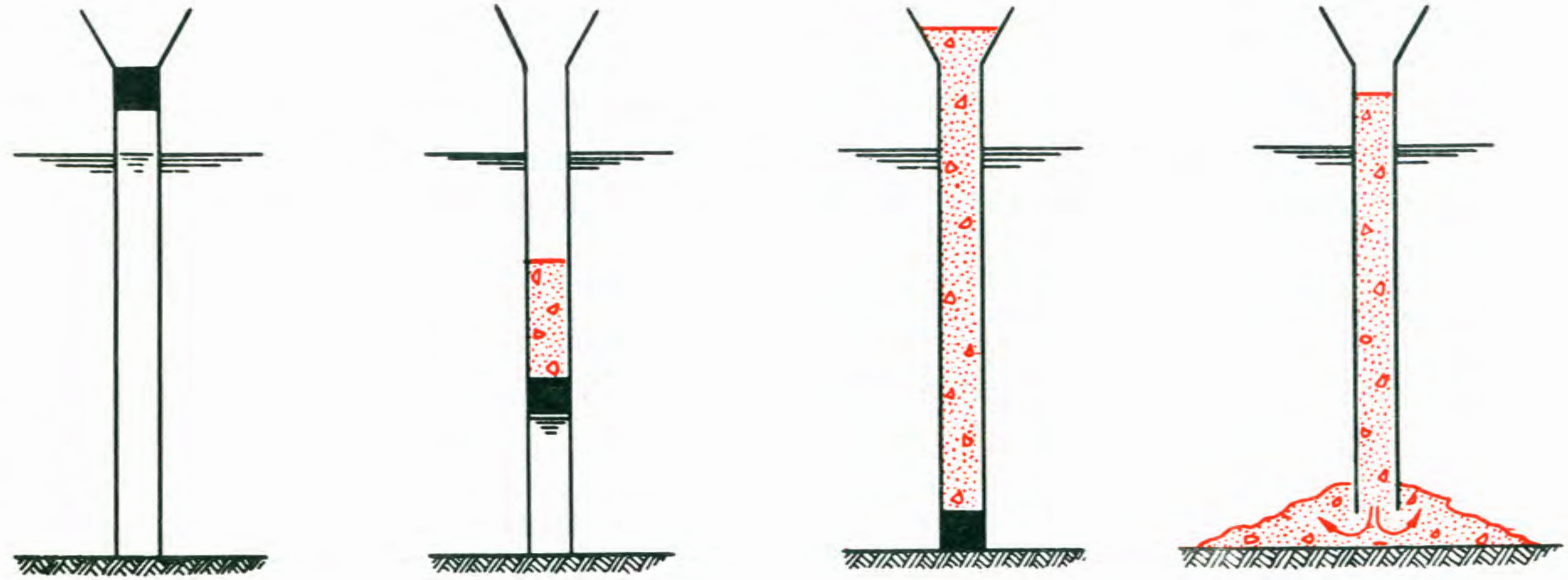

1st.
2nd.
3rd.
4th. Locations of Tren
34'
60'
1st. Tremie setting
2nd.
3rd.
4th.

FIG. 5A



(a)
Plug in place

(b)
One batch of concrete placed

(c)
Plug on bottom with tremie and hopper full of concrete

(d)
After 3(c) is reached the tube will have to be lifted to permit escape of the plug unless the bottom is sand, in which case the water driven out by the plug has probably eroded it.

This shows how a tremie operation can be started.

FIG. 5 B

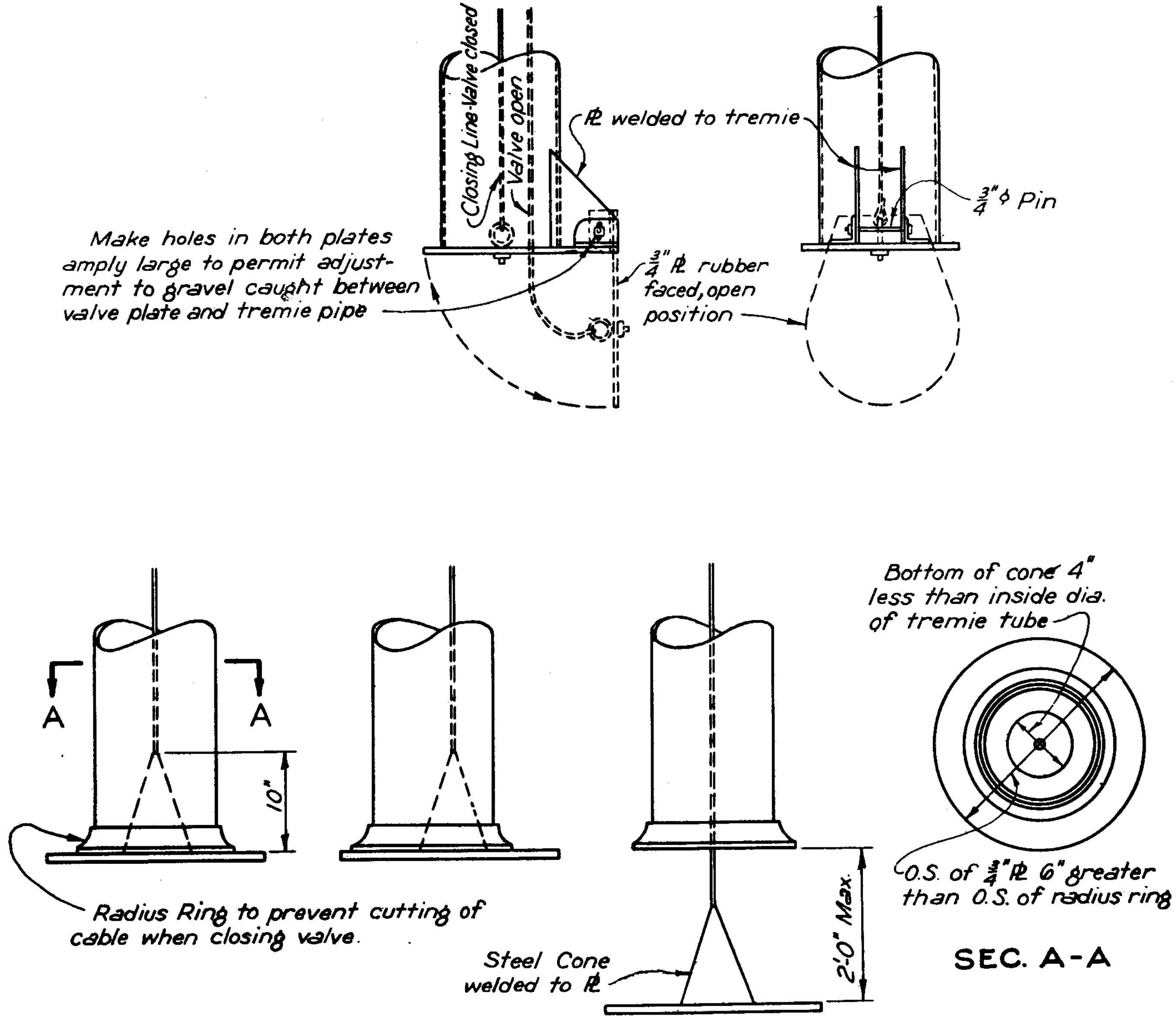

Closing Line-Valve closed
Valve open
℞ welded to tremie
Make holes in both plates amply large to permit adjustment to gravel caught between valve plate and tremie pipe
3/4" ℞ rubber faced, open position
3/4" ϕ Pin
A
A
10"
Radius Ring to prevent cutting of cable when closing valve.
Steel Cone welded to ℞
2'-0" Max.
Bottom of cone 4" less than inside dia. of tremie tube
O.S. of 3/4" ℞ 6" greater than O.S. of radius ring
SEC. A-A

FIG. 6

while being submerged and lowered is recommended. It shall then be raised very slowly during the discharge travel, the intent being to maintain as nearly as possible still water at the point of discharge and to avoid agitating the mixture. This method cannot be used if piling projects above the bottom of the excavation, preventing the seating of the bucket on the bottom of the area.

The most common method of placing concrete envisions the use of the tremies as outlined above. Figure 5-A shows how a tremie is held in place and how it is moved from one position to another without losing the charge of the concrete. Figure 5-B shows a sack of straw or a bundle of rags used as a plug to prevent the concrete from falling loosely through the tube and water. This plug also pushes the water out of the tube as the weight of the concrete on the plug overbalances the pressure of the water on the bottom of it.

Various valves have been used to stop the flow of concrete while moving from one setting to another without losing the charge. For light work, the details shown in Figure 6 have proved more or less satisfactory.

Not all concrete which is placed in water need be placed by means of tremie or bottom dump bucket. There will be occasions where there may be six inches or a foot of water in the bottom of a form which is several feet deep. On these occasions, it is permissible to use the principles of pushing the water away with the concrete by slow displacement as indicated

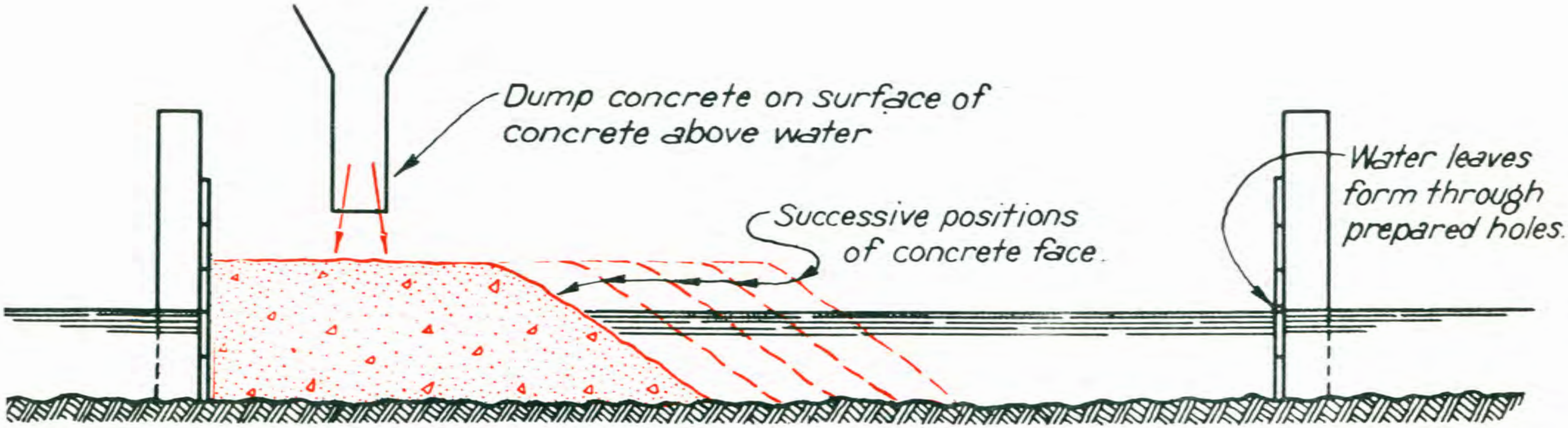

Dump concrete on surface of concrete above water
Successive positions of concrete face.
Water leaves form through prepared holes.

FIG. 7

in Figure 7. This may require the use of a small tremie to establish the concrete surface above the water. Thereafter, concrete is dumped on concrete and concrete displaces water which either flows out of the form or is pumped out. Depending on the depth of the water, there are other means of establishing a surface of good quality of concrete above the water surface. This need not be Class E concrete. It is generally designed and serves as structural concrete and can be handled with a slump of Class A concrete which is to be vibrated. The vibrating helps move the surface ahead to displace the water.

Depending upon the depth of the water above the top of the seal concrete, a sounding line or sounding pole as indicated previously will serve to keep track of the elevation of the surface of the concrete during the tremie operation. The sounding weight on the end of the pole should be large enough to provide the delicacy needed to indicate contact with very soft concrete. The tremie should be clearly and accurately marked to show the depth below the water surface of the lower end of the tube. That is, the end that must be kept several feet below the surface of the tremie concrete at all times.

Item 420.7, Foundation, states that the completed seal shall not be higher or lower than the plan grade, established by the Engineer, by more than one foot.

The seal shall be allowed to set for at least thirty-six hours before the cofferdam is de-watered. After de-watering, the top of the seal shall be cleaned off, all laitance or other soft materials should be removed, and high spots which exceed the above limitations shall be cut off and removed.

In measuring the quantity of seal concrete for payment, it will be necessary to deduct the imbedded portion of all piling in the cofferdam. The specification states that only accepted work will be included, and dimensions used will be those shown on the plans or ordered in writing by the Engineer.

C. Footings

1. Alignment and Control of Forms

It is usually necessary to have at least four stakes to provide control for footings. These are to be located on the two axis of the footings. By locating the center of the footing by stringline stretched between the stakes denoting the axis of the footing, the Contractor's carpenter can then proceed to make the form in the shape of the footing.

Item 420.18, Placing Concrete in Foundations and Substructures, states that when footings can be placed in dry foundation pits without the use of cofferdams or caissons, forms may be omitted if desired by the Contractor and approved by the Engineer, and the entire excavation filled with concrete to the elevation of the top of the footing. Where this procedure is followed, however, no measurement for payment will be made for concrete placed outside the footing dimensions shown on the plans. This procedure should be resorted to only in the case of a foundation that does not require the placing of reinforcing steel in the footing. If the foundation requires the placing of reinforcing steel, it will be practically impossible for the Contractor to place the steel in its proper position, using this system of forming.

2. Pouring and Finishing.

In pouring the concrete into the footing, the concrete should not be allowed to strike the sides of the form, as it will vibrate the supporting joists and timbers and will, in all probability, tend to move the position of the forms and footings. The top of the footings should be finished to the grade established by the Engineer and this grade should be rechecked after the placing of the concrete. A top-grade for the footing is usually marked by nailheads around the inside of the forms or by a chamfer strip, if required. The concrete should be hand floated and finished to the proper elevation.

Concrete in foundations should be placed in a manner that will avoid separation of the aggregates or displacement of the reinforcement. Suitable chutes or jointed pipes shall be provided. The specifications require that the length of chutes or jointed pipes should be such that the concrete will not have a free fall of more than three feet.

3. Check List

The elevation of the top of the footing should always be checked after placing the concrete to see that the forms have remained in the proper position and that the elevation is still correct. If it is not correct, the chamfer strip should be raised or lowered and any excess concrete removed, or extra concrete added, to bring the foundation to the proper elevation. The sides of the forms should be checked to see that they remain vertical during the placement of the concrete and that the dowel bars projecting out of the footing remain in the proper position. If form movement has occurred during the placing of concrete, they should be straightened before the initial setting of the concrete occurs. If possible, the forms should be of such character that they may be adjusted to the proper vertical alignment. The reinforcing steel should always be checked to see that it has proper support and is in the proper position in the footing before the concrete is placed. The depth of the footing should be checked prior to placing the concrete to see that the elevation set for the finished grade in the bottom of the footing conforms to the plan requirements.

4. Measurements and Records to Keep

Each footing should be checked to see that it is in the proper position on the centerline of the structure and in the proper position transversely. The size of the footing should be checked and the measurements recorded in field books along with the depth of the footing and the volume of concrete placed. It should be remembered that the volume of concrete in the footing should include only those quantities actually shown in the plan dimensions, making allowances for deductions for any piling that are projecting into the footing, excluding "H" piling.

IV. Columns, Caps and Piers

A. Columns

1. Forms

Column forms are usually made out of steel. These forms should be checked to see that they are the proper size and do not have any offsets where the sections are connected together. They should be strong enough that they will not bulge while the concrete is being placed. These forms should also be checked to see that they are so constructed to permit removal without damage to the concrete. Column forms are usually constructed in semi-circular sections that bolt together. These forms should be checked for mortar tightness so that the concrete will not be honeycomed after it is vibrated. The specifications state that the minimum thickness of metal used in forms for the cylindrical columns or shafts shall be three-sixteenths of an inch.

The forms should be made in section of such length that will facilitate the placing of concrete and the removal of forms. The bolts and rivet heads on the facing side of any column shall be countersunk. Clamps, pins, and other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms that do not present a smooth surface or do not line up properly should not be used. The metal should be kept free from rust, grease, or other foreign material that will tend to discolor the concrete.

The forms should be treated with oil and it must be applied before the reinforcement is placed. This oil should be a light, clear oil which will not discolor or otherwise affect the concrete surface. As permitted by the plans and specifications, fiber forms treated with wax or plastic may be used for the columns. This type of column form is usually used on columns of eighteen-inch diameter or less. Our present specifications do not say anything about this type of column form material. If it is to be used, a note must be placed on the plans and a special provision provided.

The position of the columns should be checked longitudinally and transversely to see that they are in the position shown on the plans. These dimensions can be checked by using the points that were used to obtain the center of the footing if they have not already been disturbed. The distance between the columns can be checked by measuring outside to outside of the forms and deducting the thickness of one column. This should give a center-to-center dimension between the columns as shown on the bent detail. Likewise, the dimension between bents may be checked in the same manner. The columns should be set vertically and kept vertical during the placing of concrete. A four-foot carpenters' level is helpful for checking the vertical alignment. The vertical alignment can also be checked by setting up a transit on the centerline of the bent and checking the position of the bottom of the column and the position of the top of the column. A rough check may be made by the use of a plumb bob, held some distance from the columns. Any method that is feasible in checking the vertical alignment should be used.

There are several methods of control of the vertical alignment. Some contractors have adjusting bolts set in the foundation of the footing in order that the alignment of the columns can be controlled with adjusting nuts. Another method is the use of dead men and cables fastened to the top of the columns in at least three or four directions.

Any of these methods is satisfactory as long as they are capable of holding and adjusting the forms in vertical positions while the concrete is being placed.

The column forms may also be plumbed by attaching a plumb bob to the form and using a long string to set the plumb bob directly over a pre-determined target marked on the footing. This method usually requires the use of two plumb bobs set at right angles to each column.

2. <u>Pouring and Finishing</u>

Item 420.18, Concrete in Columns, states that it shall be placed monolithic unless otherwise provided. Unless a construction joint is provided at the top of columns, an interval of not less than one hour and not more than two hours, shall elapse between the placing of concrete in columns and the placing of concrete for caps or tie beams. Such interval is intended to allow for shrinkage of the concrete.

Before pouring concrete in columns, the reinforcing steel should be checked to see that it is properly spaced and projects the rquired distance above the top of the column into the tie beam or cap. A suitable jointed pipe with a hopper attached to the top of it should be provided inside the reinforcing steel cage to allow the placing of concrete in such a manner that it will not have a free fall of more than three feet from the bottom of the chutes to the top of the footing or the top of the concrete. These jointed pipes should be adjustable in order that as the height of the concrete inside the columns increases, the sections may be removed. These pipes are provided so that the concrete will not spatter the reinforcing steel cage and to prevent segregation of the aggregates.

The concrete should be vibrated as it is being placed in the columns to eliminate any honeycombed areas along the edges of the forms or in the interior of the columns. It is sometimes necessary for a man to climb down inside the cage of reinforcing steel to properly vibrate the concrete that is being placed.

The Inspector should be assured that the concrete is being adequately vibrated as it is placed. After the concrete is poured to the top of the column, the form should be rechecked to see that it remained in a vertical position in both directions and is at the correct distance off the centerline of the structure.

Item 420.21, Curing Concrete, states that all concrete except as noted, shall be cured for a period of four curing days. For a Type 1 or Type 2 surface finish, columns will have to be rubbed prior to the end of the four curing days required by the specifications. Thus, it will be necessary for the Contractor to wrap the columns with curing mats and keep them wet during the time he is putting the initial rub on the columns. It is noted that, in general, the curing of columns after the removal of forms is usually neglected. The inspectors should see that the Contractor has proper equipment and has made provisions to keep the cotton mats wet during the entire four-day curing period.

After the column forms have been removed and all repair and pointing has been done, the first rubbing should be done. When the pointing has set sufficiently to permit, all surfaces requiring surface finish shall be wet with a brush and given a first rubbing with a No. 16 carborundum stone or equal. The rubbing shall be continued long enough to bring to the surface a paste and it should remove all form marks and projections. The use of cement to form a surface paste should not be permitted. Unless this work is inspected, the finisher will normally try to use a cement to form a surface paste instead of rubbing up the concrete with a carborundum stone.

If a second rubbing is not specified, chamfered corners shall be rubbed in the first rubbing and the material which has been ground to a paste in the rubbing process shall be spread uniformly over all rubbed surfaces by striping with a brush. The mortar on the surface shall be allowed to take a reset. The surface then shall be washed down with clean water and all rubbed surfaces shall be left with a clean, neat, and uniform appearance and uniform in color.

If a second rubbing is to follow the first rubbing, the material ground into a paste in the first rubbing shall be spread carefully and uniformly over the surface and allowed to take a reset. Washing down at this time is not required. The second rubbing shall be performed as follows:

During the process of conditioning the completed structure for final acceptance, the surface of the entire structure requiring finish shall be clean and free from drip marks and discoloration and shall be given a final finish rubbing with a No. 30 carborundum stone or equal. Upon completion of this rubbing, the surface shall be striped neatly with a brush and the mortar on the surface shall be allowed to take a reset. The entire surface shall be washed down with clean water and left with a neat, clean and uniform finish.

When membrane curing is used on a column, it shall not be applied prior to the first rub. See Section 420.1 (in Table 1). Prior to the second rub, or during the final cleanup of this structure, if a second rub is not required, the pigmented cured compound should have disappeared from the surface. If it has not, it shall be removed completely by brushing, buffing, or other means as necessary.

For columns which do not require a surface finish, no rubbing will be required unless some portion of the column is not true or has porous or honeycomb areas. In case these defects occur, the area affected shall be given a first surface rubbing. This rubbing should extend over sufficient area around the finished portion to blend the rubbed area into the surrounding unfinished surface. This shall not be construed to require the rubbing of large areas of unblemished surfaces to gain absolute uniformity of color and texture on the entire surface of the column. The column should be free of discoloration and should present a uniform appearance.

If honeycomb is encountered after the column forms have been removed, all loose material should be removed before the repair work is started. A latex base or epoxy base patching adhesive shall be used in patching the defective areas when the size or depth warrants.

No extra compensation is to be allowed for the extra work or materials involved in repairing or replacing concrete. Any drip marks or runs occurring on the columns from subsequent concrete operation should be removed before acceptance of the structure. Where a Type 1 surface finish is required, these runs should be removed in the final rub. Where other types of surface finish are required, the runs would have to be removed after the initial rub or prior to the acceptance of the job.

B. Piers

1. Forms

Pier forms are usually made out of plywood facing with vertical studs made out of 2x4's, 4x4's, or 2x6's. These vertical studs should be faced so that the clear distance between the edges of the stud is not more than sixteen inches (if three-quarter plyboard is used). This type of form is used for the main wall of the piers. The forms are then held together by means of walers and 3,000-lb ties, spaced at two-foot centers, vertically and horizontally. These walers are usually doubled 2x4's or larger size timbers and extend past the edges of the forms at each end. They should be cleated across each other at each end. These cleats may be 2x4's or larger timbers that are attached to the wales that run the length of the pier.

Some contractors prefer to use metal forms for holding the concrete. This usually occurs where the piers have the same dimensions and approximately the same height on long structures. What has previously been said about checking forms under columns would apply to these metal forms.

The alignment and control of pier forms can be controlled in the same manner columns are controlled. This is particularly true when the pier forms are not located in a cofferdam. On the other hand, if the pier forms are located in the cofferdam, they can be braced off the sides of the cofferdam. The longitudinal and transverse centerlines can be checked from the previously set centerline points that were used for the cofferdam. Where pier forms vary in thickness from the bottom to the top of the pier, it is necessary that the bottom of the pier be accurately positioned on the footing which has previously been poured. The top of the pier should be checked to see if the centerline at the top and the centerline at the bottom is the same. This may be accomplished by dropping a plumb bob from the top of the pier to the center point of the pier at the top of the footing. After the wall forms have been set, lined, and braced, the concrete may be placed. It is usually advisable to drop plumb bobs on each end of the pier, since they are rather wide and it would be easy to get the pier in a skewed position.

2. <u>Pouring and Finishing</u>

It will be necessary to use a jointed pipe that is adjustable in height as the concrete is placed in the pier form. This pipe will have a hopper attached to the top of it to receive the concrete as it is deposited from the concrete bucket. The placing of concrete shall be so regulated that the pressure which is caused by the plastic concrete shall not exceed the loads used in the design of the forms. In tall piers, this will require a maximum rate of four feet per hour. As the concrete is placed, it should be compacted and a mortar flushed to the surface of the forms by continuous working with the mechanical vibrators of an approved type. Vibrators should be applied to the concrete immediately after deposit and should be removed throughout the mass thoroughly working the concrete around the reinforcement and into the corners and angles of the forms until it has been reduced to a plastic mass. The vibrator should not be operated so that it will penetrate or disturb layers previously placed or hardened. Vibration should be of sufficient duration to accomplish thorough compaction and complete embedment of all enforcement but should not be done to an extent that it will cause segregation.

What has previously been said about finishing columns and caps applies to piers also. All metal appliances used inside the pier forms to hold them in correct alignment should be removed to a depth of at least one-half inch from the surface of the concrete and shall be so constructed that the metal may be removed without undue injury to the surface due to chipping or spalling. Such devices when removed shall leave a smooth opening in the concrete surface. Burning will not be permitted. These ties are held in place by devices attached to the walers. Each device is capable of developing the strength of the tie and should be of the adjustable type to allow aligning the form. Any metal or wooden struts which are separate from the form shall be removed entirely as the concrete is being placed.

After the concrete is placed in the pier, the forms should be checked to see that they have remained in position and if they have moved, they should be adjusted by the method provided on the form details. The top elevation of the pier and all bearings should be checked to see if they are at the proper elevation and all anchor bolts should be checked to see if they are in the proper location with reference to the centerline of the bridge and the centerline of the pier. Anchor bolts should also be checked to see that they project sufficiently from the top of the shaft or pier.

The elevation of each bearing seat should be checked prior to the initial set of the concrete in order that any low place may be filled in and the anchor bolt adjusted to the proper height before the concrete takes its initial set. This is one of the most overlooked items of the construction inspection in the District. It is much easier to get these bearing seats elevations correct as the concrete is being placed than to come back later and build up with mortar or shims or have to bush hammer to get the proper elevation on the top of the pier.

It can well be understood that these elevations are hard to check when the wind is blowing strongly. The Inspector should notify the Contractor he would not be able to pour under such conditions.

The Contractor should never be permitted to start placing concrete in a tie beam or cap form attached to a column that will not permit vertical adjustment of the cap forms. If these forms do not have some kind of vertical adjustment and the weight of the concrete causes the forms to settle, it will be impossible to raise the cap or tie beam to the proper elevations.

It should always be remembered that if the forms are in the proper position in the beginning, it is not proper to assume that they will remain in that position throughout the pouring operations and all dimensions should be checked before pouring proceeds. If these checks are made during placing operations, they can usually be corrected by the adjustments that are provided for in the forms. It is not possible to make these adjustments after the concrete has obtained its initial set.

C. Caps

1. Forms

Most cap forms are made out of plywood supported on stringers which rest on heavy timbers or heavy beam sections attached to the columns by means of collar clamps. These collar clamps are usually made out of metal and bolted together.

On trestle bent piling, collars are usually clamped to the piling by means of bolts and 2x4's or 2x10's. The supporting beams for the cap forms are then set on these timber collars. These stringers or beams should be of sufficient section to carry the load between column supports or pile bent supports without deflection due to the weight of the concrete. Two-by-four joists on sixteen-inch centers, or less with plywood decks, are usually placed on top of these stringers to form the bottom of the cap. The side forms of the caps are usually made with 2x4 studs on sixteen-inch centers faced with three-quarter-inch plyboard. These side wall forms are capped at the top and bottom by 2x4 plates. Walers for the cap form should be spaced at such intervals to hold the form securely to the designated line. The specifications state that a row of walers shall be placed within six inches of the bottom of each placement. Where the walers are not continuous, they shall be scabbed at least four feet on each side of the joint to provide continuity. This is an item which is easily overlooked and usually is a point where the forms will bulge. The cap plates for the top and bottom of the forms should be carefully selected for straightness. The 2x4 joist on which the plywood rests should be of sufficient length to provide room for workers and to provide kickers to align the side forms. These kickers may be 2x4's or preferably, made of metal with turnbuckles so that the forms can be adjusted to the line and grade set by the Engineer. The top of the cap form should be cleated across with 2x4 cleats on two-foot centers or with metal braces that will keep the width of the top of the cap constant.

The centerline of the cap should be placed on the bottom of the cap form and the Contractor can set the length of the caps by measuring to each end. The centerline of the bent should be marked on each end of the form so that the Contractor may set his side form the proper distance off the centerline of the bent. After the Contractor has set his forms to the centerline and has placed the reinforcing steel in the cap, the bottom of the cap should be checked to see if it is at the proper grade. The side forms should be checked to see if they are vertical and dimensions of the cap should be checked to see if they conform with the plans. The distance between bents should also be checked to see that the center-to-center distance is correct. After this is completed, the Contractor can place the chamfer strip for the top of the cap elevation. This strip should be set by the Engineer with a level. This can be accomplished by setting the elevation at each end, or if the cap has a crown, it will be necessary to set the elevation at the required points as well as each end. After the chamfer strip is set, it should be checked again by level.

2. Pouring and Finishing

The concrete should be placed in continuous horizontal layers approximately twelve inches in thickness. It should be deposited directly as near its final position as possible. Depositing large quantities of concrete in one end of the cap and running or working it along by vibrating should not be allowed. After all the concrete is placed in the caps, the grade on the tops of the caps should then be checked by levels and the chamfer strip checked to see that it is still at the proper elevation. The side forms should be checked to see that they remain vertical during the pouring and this may be accomplished by placing a stringline from one end of the forms to the other on the inside of the forms with a one-inch spacer block provided at each end. By using a spacer block of the same dimensions to hold the stringline off the forms, they may then be checked from one end to the other to see that they remain perfectly straight. It is essential that the end points be the proper distance from the centerline of the cap. After the forms have been checked to see if the caps remain in the proper position and the sides are vertical and straight, the Contractor should then float and finish the top of the caps in accordance with the type of surface finish specified.

After twenty-four hours, the side forms should be removed and the Contractor can finish the sides of the cap as required by the contract. After the first rubbing is completed, the Contractor should continue the curing for the required period. The forms supporting the bottom of the caps should remain in place for the minimum of five days unless the Contractor elects to remove the forms by the beam break method. If the forms are removed in less than four days, it will be necessary to continue curing the bottom of the caps by membrane curing.

Holes for anchor bolts in the cap may be drilled or may be formed by the insertion of oiled wooden plugs or metal sleeves in the plastic concrete. The plugs or sleeves should be removed after the concrete has set. When holes are formed in this manner, they should be of such diameter to permit horizontal adjustment of the bolts. The bolt shall be carefully set in mortar. In lieu of the above method of placing anchor bolts, they may be set to the exact location in the concrete when it is placed. In this case, the bolts should be set in templates so that they are in correct position with respect to the transverse and longitudinal centerline. The projection of the bolts above the tops of the caps should be as shown on the project plans. The cap elevation at these joints should also be checked to see that it is the proper height and that the bolt projection be of sufficient length to receive a washer and nut after the shoes are set.

V. Girders and Floor Systems

A. Prestressed Concrete Girders

1. Inspection and Handling

The inspection of the fabrication of prestressed concrete beams is usually handled by File D-9. This inspection by File D-9 includes the placing of the concrete and stretching of the tendons and other placements of reinforcing steel in the girders. File D-9 casts cylinders for the Type F concrete that goes into manufacture of these prestressed beams and they control the quality and the strength of the concrete by this means. After the beams are fabricated and the cylinders tested, File D-9 issues test reports for each beam stating the length of beam and the strength of the concrete. The lab report will usually have the erection number that is to be placed on the beam. The beams are stamped by File D-9 before they are shipped to the project.

After the beams arrive on the job, the Inspector should check each beam to see that it is stamped by File D-9 and also check the markings and erection numbers from the erection layout that has been previously approved. This erection layout sheet shows the layout, type member, erection number of each girder, bearing pads, etc. He should also have other sheets of the fabrication details showing the member type, skew angle, dimensions for diaphragm holes, beveled neoprene pad sizes, erection devices and inserts to be used in the forming, etc.

The Inspector should check each beam to see that it complies with Item 425.7, Workmanship and Tolerances. The variation from shop plan length should not be over, plus or minus, one inch; variation from plan height, box-type beams, one-quarter inch; other type beams, plus or minus, one-half inch. The maximum sweep for the beam should be one-quarter inch per ten feet of length and for box-type beams, three-quarter inch total sweep in the total length of the beam. Each beam should be checked for out of square(vertical or horizontal) or deviation from the plan skew angle by the maximum of one-eighth per foot of dimension. The bearing area of each beam should be checked to see if it is out of perpendicular with the vertical axis which allows a maximum of one-sixteenth of an inch.

Honeycomb in the bottom of beams at the bearing point should not exceed fifteen per cent of the bearing area, (the width times the length). No tendons should be exposed and the honeycomb depth should not exceed one inch. Honeycomb which does not exceed these dimensions shall be chipped out to sound concrete and repaired prior to acceptance.

Care must be exercised at all times when handling prestressed beams. In general, members should be lifted only near the ends and always in an upright position. The fabrication and erection plans should indicate the method of handling in such detail as to preclude the possibility of overstressing any part of the member. Fine hair cracks or checks on the surface of the prestressed beam which do not extend to the plane of the nearest reinforcement will not be cause for rejection unless such cracks are so numerous and extensive as to indicate inadequate curing, in which case, the member will be rejected. Diagonal cracks on the vertical surface which indicate damage from torsion will be subject to a structural review prior to acceptance. Vertical and horizontal cracks which are one-sixteenth of an inch or less in width and which tend to close up on release of stress are acceptable. Cracks in excess of this are subject to review prior to acceptance. Cracks which extend into the plane of the reinforcement are prestressing steel and which are acceptable otherwise shall be repaired as required by Item 420, Concrete Structures, cured and rubbed prior to acceptance. The reinforcing steel placement stirrups and hairpins (T and R) should be checked to see that the steel has a minimum clear cover of concrete of one inch. These bars should be placed within two inches of plan location. Beams which arrive on the job but do not conform to the requirements of the specifications should be reported to the Field Engineer who, in turn, should report to the Resident Engineer. If these discrepancies are few and minor in nature, there is a possibility of the beams being accepted after this information has been cleared through the District. The surface on the beams may be such that the vertical surfaces shall be practically free from porosity. Air pockets which are present should be scattered and should not exceed three-eighths of an inch in surface dimension. On the sloping surface of the lower flange, more porosity is to be expected but should be scattered and general and not greater than five-eighths of an inch in surface dimension. Porosity in excess of the above should be corrected by filling with grout containing some white cement to match the existing surface and blended with a rubbing stone. The top of the beam should be checked to see that it has been rubbed and floated with a wooden float. This should be done at the plant, and it should be checked to see that it is properly done when the beams arrive on the job. Sound concrete should be the criteria of inspection. All surfaces of the beams should be practically free from discolorations and should present a uniform appearance. Any unsightly discolorations should be removed prior to final acceptance.

2. Setting the Girders

The bearing seats for the beams should be previously bush hammered, or steel-troweled finished and checked to see that they are at the proper elevation and are of the proper dimension. The centerline of each bearing area should be inscribed on the bearing seat, longitudinally and transversely. This will facilitate in setting the neoprene bearing pad in the proper position. The bearing pads that the beams sit on are specified on the plans by hardness (durometer reading) and by size and configuration. The Inspector should check to see that he has test reports on these bearing pads before he permits the setting of the girders. He should also check the allowable dimensional tolerances on these pads when they are received on the job. These tolerances are for constant thickness bearing pads. Variation from plan dimension allowed is plus one-eighth minus zero inches. Variation in thickness between any two points of the same pad is one-thirtysecond of an inch; variation in length or width,plus or minus, one-eighth of an inch; variation in diameter of holes,plus or minus, one-sixteenth of an inch; variation in distance from center to center of holes, plus or minus, one-eighth of an inch; variation from edge of pad to center hole, plus or minus, one-eighth. For beveled bearing pads, the same tolerances are in effect, except the thickness of the pad at any one point may not vary more than one-sixteenth from the thickness shown on the plans.

After the bearing pads are placed in position on the caps, the girders may be set in position on the pads and if all of the previously mentioned tolerances have been checked, the beams should have an even uniform bearing on the pad and the cap. The beams should be checked to see that they are the proper distance off the centerline of the bent and the distance between parallel beams should be checked to see that it is correct. The ends of the beams should be checked to see that they are within allowable tolerance off the centerline of the bent. On the fixed end of the beam, it will be necessary to set the hole over the "M" bars which have been previously embedded in the cap. These bars should be checked as they are placed when the concrete cap is poured to see that they are in the correct position to receive the prestressed beams when they are ready to be erected.

3. <u>Concrete Diaphragms</u>

The concrete diaphragms that go at each end of the span and usually in the middle of the span are usually poured prior to the placing of the concrete deck slab. The forms for these diaphragms may be either of metal or steel. The adequacy of these forms should be checked prior to permitting the pouring of concrete. After the concrete has reached a minimum age of twenty-four hours, the nuts of the one-and-one-quarter-inch round L-bar shall be firmly tightened. This is the bar that runs through the middle diaphragm of the span.

The "N" bars in the end diaphragms are No. 8 bars, and they do not extend beyond the outside of the exterior beams. These bars should stop two inches from the exterior of the outside beams and the holes should be well grouted to insure bond with the bar end and the prestressed girder. These bars may be continuous through all beams of the span or may be made up of a series of bars arranged to lap a minimum of twenty bar diameters within the diaphragm. The concrete in these diaphragms should be placed the total depth shown on the plan. The Contractor should not be permitted to pour these diaphragms above or below the elevation shown on the plans. A cut or fill for the top of each diaphragm should be shown on the beams at each diaphragm. The bars H-2 and J-1 should be placed on one-foot centers ($\pm$) and the top of these bars should be such that they will not protrude to the top of the concrete deck. These bars should be checked to see that they are fabricated within the acceptable tolerances set out in the specifications before they are placed in the diaphragm. It is to be noted that there is a permissible construction joint at the top of each diaphragm. If the Contractor so elects, he may pour the diaphragm with the slab. There is no reason whatsoever to permit the Contractor to pour these diaphragms in a haphazard manner. Inspection of these diaphragms should receive as much attention as any other part of the structure.

B. Welded Steel - I-Beams - Floor Systems and Shoes

1. Shoes

The shoes, after they arrive on the job, should be inspected to see if the top bolster of each shoe is fabricated in such a manner that 75 per cent of the long dimension shall be true to 1/32nd of an inch. The top bolster shall be true to 1/32nd of an inch across its entire width on the short dimension. Normally, these items are checked by D-9 before they are sent to the project; however, these particular dimensions should be checked after they arrive on the job. They should be checked to see that they conform to the dimensions shown on the plans.

Using a sharpened inscribing tool, and a carpenter's square, scribes should be cut on the concrete surface, extending six inches beyond the area of each bearing seat for the shoe, one scribe along the line of the beam and one scribe at ninety degrees to the centerline of the beam, a small red paint spot placed on the nine-degree scribe line on the high seat of the bearing line. An accurate elevation is then secured for this paint spot. From the scribes in this bench mark, the Contractor can then bush the bearing seat to the exact line engraved. Care should be exercised to obtain a neat grade, free of depressions. Occasionally, through carelessness or error in reading the cut, the bearing seat may be bushed below grade.

If this happens, the area should be bushed level at the lowest point and a steel shim placed to bring the bearing seat to the correct elevation. When the bushing has been satisfactorily completed, dry cement should be sprinkled on the bushed area to level the bearing seat without voids. The bearing plate of this shoe is then set and checked for line and grade. Bearing plates should then be picked up and the seat area inspected for full bearing on the concrete and cement. The fixed and expansion shoes are now ready to be placed on the bearing plates.

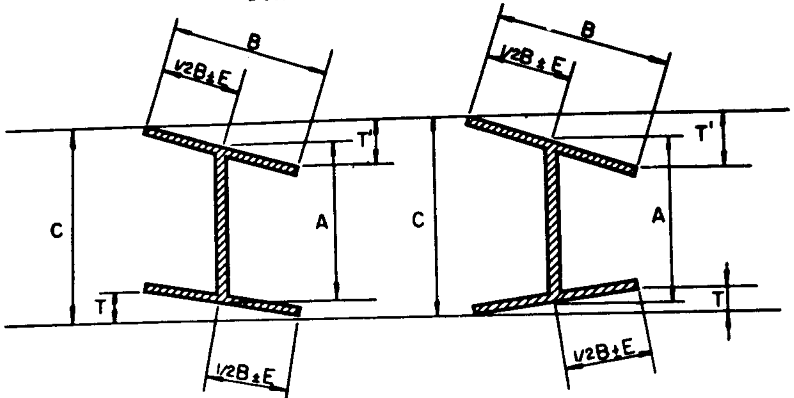
2. Welded Steel I-Beams

As the members arrive on the job, the shop drawings that have previously been approved by File D-5 and sent to the Resident Engineer should be on hand and the Inspector should take these drawings and check each beam to see that it is marked in accordance with the erection diagram. He should also check to see that the beams are stamped by the inspection agency and that all matched marks are made and that these matched marks are stamped into the metal. The material should be stored above ground on platforms, skids, blocking, or supports approved by the Engineer. The material should be kept free from dirt, grease, or other foreign matter and should be protected as nearly as practicable from corrosion.

The fabrication and rolling tolerances for rolled shapes, plates, bars, wide plan sections, built-up welded girders, and other welded assemblies should be checked to see that they conform to the requirements of Appendix B of the Texas Highway Department Bulletin C-5. The Inspector should check to see that the I-Beams and girders are fabricated with a tolerance no greater than the following: The plane of the bearing area of beams and girders shall be perpendicular to the vertical axis of the beam within one-sixteenth of an inch. Correction of the bearing area of the above tolerances shall be with heat, or external pressure, or both. Correction shall not be done by grinding or milling.

The Inspector should check to see that all bearing stiffeners are welded to the proper flange. The reason for this is that the specifications require that welds should not be made across transverse flanges that are in tension. On continuous I-beams, the tension flange changes over the interior supports. The shop drawings and plans will clearly show to which flange the intermediate stiffeners and bearing stiffeners should be welded. The specifications require only a tight fit for intermediate stiffeners and this is defined to be as having at least one point bearing of the stiffener on the flange and no more than one-sixteenth of an inch maximum clearance at any point. The requirement to ASTMA-6 for webs of wide flange sections (except at splice points) shall be that the maximum deviation from flatness shall be D/150. (See Figure 8.)

PERMISSIBLE VARIATIONS IN CROSS-SECTION FOR WIDE FLANGE SHAPES.



Section Nominal Size, in.	*A*, Depth, in. Over Theoretical	*A*, Depth, in. Under Theoretical	*B*, Flange Width, in. Over Theoretical	*B*, Flange Width, in. Under Theoretical	*T* + *T'*, Flanges Out of Square, max, in.	*E*, Web off Center, max, in.	*C*, Maximum Depth at any Cross-Section over Theoretical Depth, in.
Up to 12, incl.	1/8	1/8	1/4	3/16	1/4	3/16	1/4
Over 12	1/8	1/8	1/4	3/16	5/16	3/16	1/4

A is measured at center line of web.
B is measured parallel to flange.
C is measured parallel to web.

TABLE XIX.—PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR WIDE FLANGE SHAPES.

Wide Flange Shapes	Permissible Variation
Camber and sweep	$\frac{1}{8}$ in. $\times$ $\frac{\text{number of feet of total length}^{a}}{10}$
When certain sections[b] with a flange width approximately equal to depth are specified on order as columns:	
Lengths of 45 ft and under	$\frac{1}{8}$ in. $\times$ $\frac{\text{number of feet of total length}}{10}$ but not over $\frac{3}{8}$ in.
Lengths over 45 ft	$\frac{3}{8}$ in. + $\frac{1}{8}$ in. $\times$ $\frac{\text{number of feet of total length} - 45}{10}$

DIMENSIONAL TOLERANCES

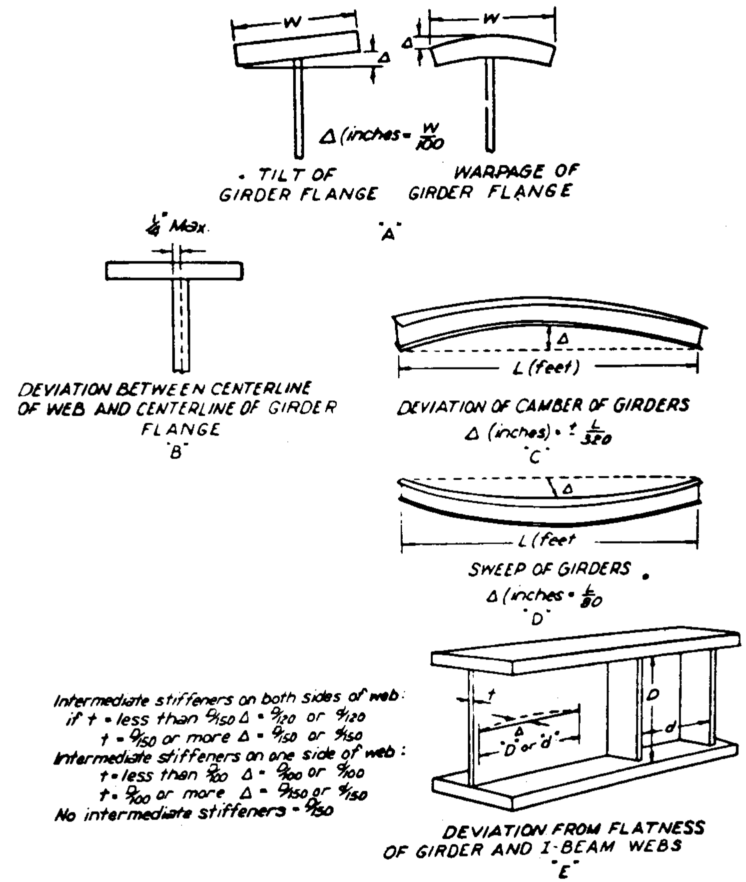


FIG. 8

The Inspector should check the webs and flanges of girders and I-beams to determine that the distance between the centerline of the outer face of a web or flange shall not deviate from the centerline of the outer face of the opposing web or flange by more than one-eighth of an inch.

The structural steel, as it has been delivered to the job, has been inspected during fabrication and should have been handled during shipment with proper care; however, errors occasionally occur in fabrication and do escape detection by the shop Inspector. That is the reason the Inspector in the field should check the beams as they are delivered to the project. Occasionally, some pieces are damaged during shipment or during unloading and hauling. If the Inspector finds any unsatisfactory material, he should take the necessary action to insure himself that the metal or pieces are placed in a satisfactory condition before they are erected.

The Inspector, after checking the above-mentioned items, should also check the metal, itself, to see that seams, holes, or laminations are not in the metal, and if they are, they should be examined as to their depth and seriousness. The correct position of bearing stiffeners and cover plates is important and if there are any errors in the location of these items, it should be brought to the attention of the Engineer. Any corrections of these items should be made prior to erection.

Item 441.26, Methods and Equipment, states that before starting work, the Contractor shall inform the Engineer fully as to the method of erection he proposes to follow and as to the amount and character of the equipment he proposes to use, the adequacy of which shall be subject to the approval of the Engineer. The Contractor is required by the specifications to submit erection plans for the erection of plate girders (riveted, bolted, or welded, trusses, and for all railroad underpass structures). Steel erection plans for I-beam units will not be required unless specified on the plans. Plans submitted by the Contractor shall be complete in all detail and procedures, sequence of work, equipment to be used, etc. If the plans are complete as outlined, a check can be made of the adequacy of the proposed erection procedures.

Where the Contractor proposes to use falsework to support part of the load during erection, these items shall be prepared on detailed plans and submitted to the Engineer for approval. The falsework plans should be complete in all detail and members, connections, equipment, etc., so that a structural check can be made of the proposed falsework. The erection plans and falsework details should be submitted to the District Office for review and correction prior to giving approval of the Contractor's procedures. After approval of the Contractor's drawings, the Engineer should make sure, by constant checking, that the approved erection plans and erection methods are being followed.

Most of the I-beam and plate girder units that we use in the Highway Department are of continuous unit nature. This type of units requires details of design and construction which the field forces ordinarily need not know in the handling of erection of simple spans.

The splices in continuous beam spans are located very closely to points of dead load contraflecture; therefore, for the intent of the design to be carried out, the splices should be free of bending moment after erection until welding of the steel portion of the structure is completed. This is assured, first, by having beams which are to be spliced before placing on the piers in correct relative alignment, vertically as well as horizontally at all times when the splice is being made. Shop drawings generally show elevations of the stringers both at the piers and at the splices. These are necessary in cases where the bridge is on a vertical curve as the individual sections are not cambered to parallel the roadway.

The second requirement is that, before making splices in any line of stringers after the beams have been placed on the piers, all of the stringers in that line should be in place, self-supported to proper line and grade by means of temporary connections for sure transfer at all points where splices are to be made. (See Figures 9, 10, 11, 12, and 13.)

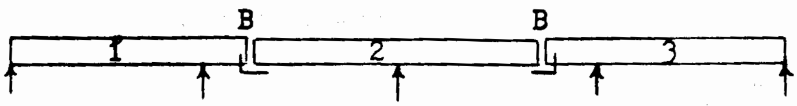


Figure 9

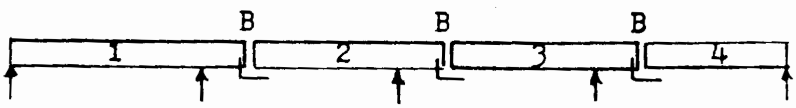


Figure 10

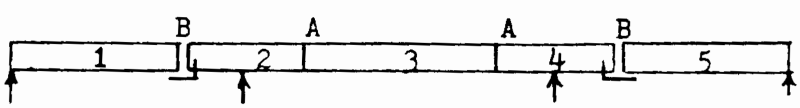


Figure 11

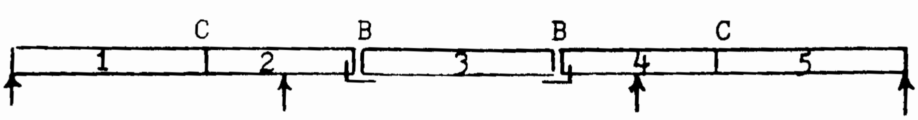


Figure 12

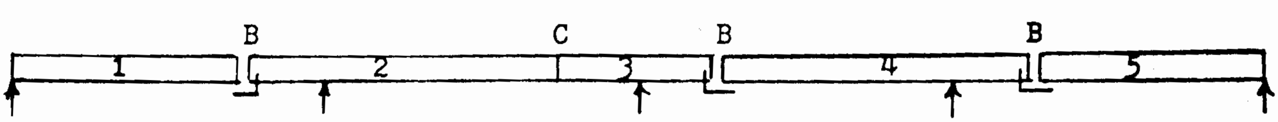


Figure 13

The second requirement is for the ideal condition. There are occasions where it may be disregarded. For instance, in Figure 10, the splice between Beams 1 and 2 could be made before Beams 3 and 4 are erected. The same is true of the splice between Beams 3 and 4 in Figure 13. This splice may be made before Beam 5 is erected. In Figure 9, however, the splice between Beams 1 and 2 should not be made before Beam 3 is erected and is supporting Beam 2 at proper height. It is satisfactory to make a splice in the air when line of stringer is only partially erected if the shear at the splice in question is between 20 per cent and 38 per cent of the weight of the beam which was last put in place.

If the fabrication of the beams in the work in Step No. 2 has been properly done, the tops of the stringers will conform within acceptable tolerances to the profile of the roadway. If, at this stage of the erection (due to poor fabrication), the opening between beam ends for welded splices is not suitable for welding, the fabrication should be corrected in the field. The root opening should be made uniform by cutting, or chipping and grinding. A cutting torch may be used for the heavy work.

In most designs where a complete line of stringers can be erected before any splices are made, the erection is not complicated. (See Figures 9 and 10.) All that is necessary for proper erection is temporary brackets or clamps on each cantilever end of the beams for the support of the floating ends of the adjoining beam.

a. Be erected with a falsework bent at the splice and the welding done with the beams in a final position, or

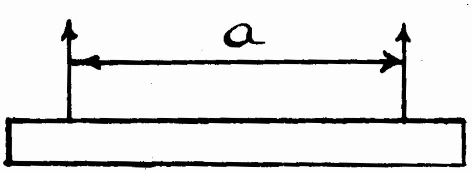
b. Two beams may be set to proper relative position on blocking on the ground, the splices made, and the larger piece then raised to position on the piers. (See Figures 11, 12, and 13.) Such practice ordinarily requires the handling of a beam about ninety feet long and weighing about sixty tons. This method is generally favored as it eliminates the necessity for falsework.

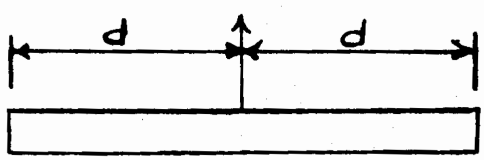
It should be remembered that long beams are relatively limber in the transverse direction and can be severely damaged by careless handling. The L/B ratio in the compression flange is higher at this time than will be the case after the diaphragms are installed. If the L/B ratio were not a factor to be considered and an erection stress of 24,000 PSI was used, the 36-inch 150-lb beam would support its own weight with a distance of 231 feet between supports. The 33-inch 130-lb beam would span 222 feet and the 30-inch 180-lb beam would span 208 feet. Handling stresses in these beams depends upon many factors other than the distance between points of pickup. There is no general rule which will apply both safely and economically to all cases.

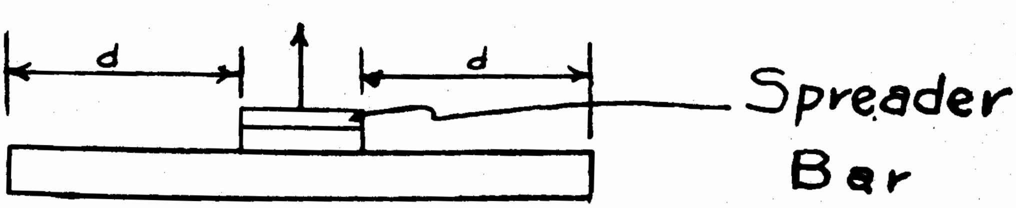
It is obvious that the length of span just mentioned is ridiculously long for safe use in steel erection. After much study of actual design and successful erection procedures, the following values have been arrived at and should not be exceeded.

Size Beam	Distance (Dimension a) Between Hooks on Two-Point Pick-up
30" WF	74 Feet
33" WF	80 Feet
36" WF	85 Feet
Plate Girder 14" Flange	100 Feet

Size Beam	Overhang (Dimension d) When Using a Single Line Pick-up, with or without a Spreader
30" WF	37 Feet
33" WF	40 Feet
36" WF	42 Feet
Plate Girder 14" Flange	50 Feet







In case these values must be exceeded, some means must be used to stiffen the compression flange until such time as permanent diaphragms are installed. There are various ways in which this temporary stiffening may be done. One scheme which can be detailed to serve satisfactorily is shown in Figure 14.

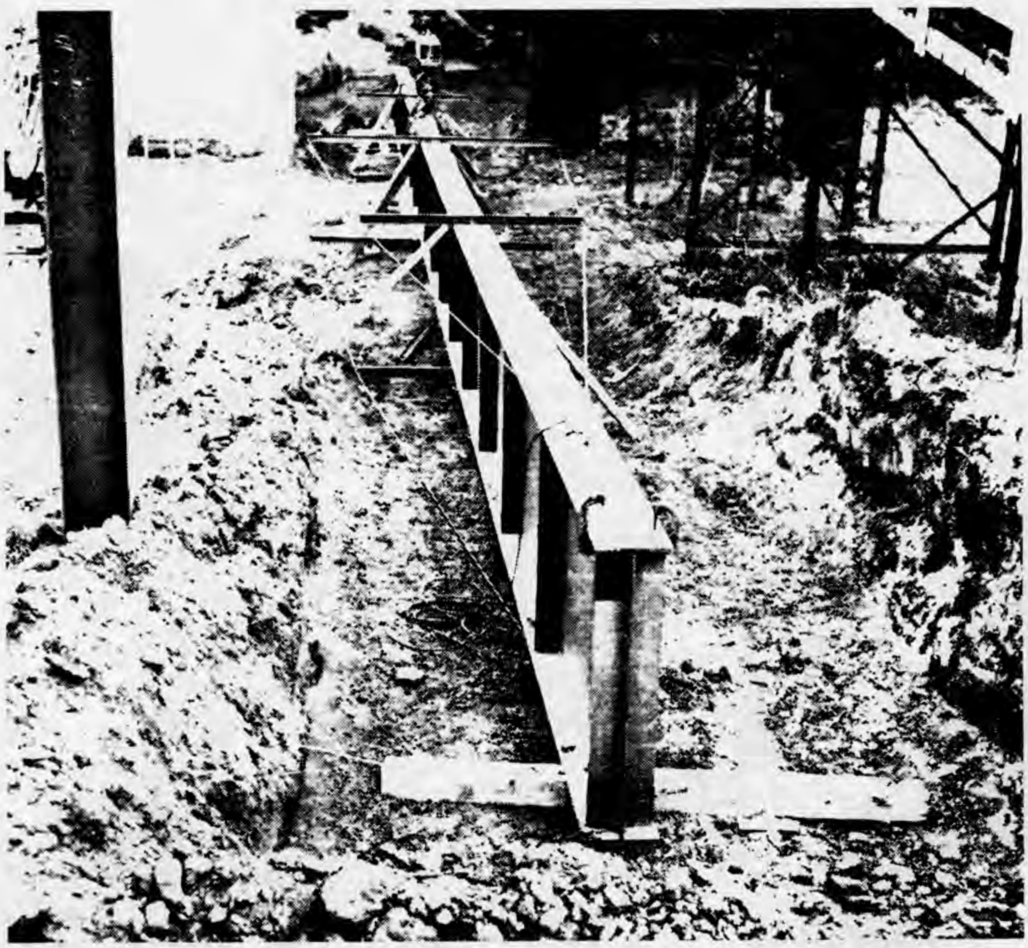


FIG. 14

B. <u>Welding the Splices</u>

Beams or girders to be spliced on the ground by welding should be carefully graded and blocked to conform to the blocking diagram. This blocking diagram is always shown on the shop plans and is usually shown on the contract plans unless the bridge is on a straight grade. (See Figure 15.) Through the use of similar triangles obtained from the blocking diagram, the dimensions needed for grading the beams may be found.

If the splice between Beams B and C is to be made on the ground, transfer the baseline running through the end of Beam A by subtracting Dimension X from both Y and Z. This will leave a double triangle as shown on Figure 16. The length of each beam will be shown on the diagram. In triangle ABE, sides AB and BE are known. In triangles ACD, side AD can be obtained by adding the lengths of Beams B and C. Then, by similar triangles, BE/AB = DC/AD, or DC = AD x BE/AB. Side N in the sketch equals DC; therefore, N equals length of Beams B and C times A divided by length of Beams B. Dimension B is known, so M may be found by subtracting B from N. M is equal to N minus B.

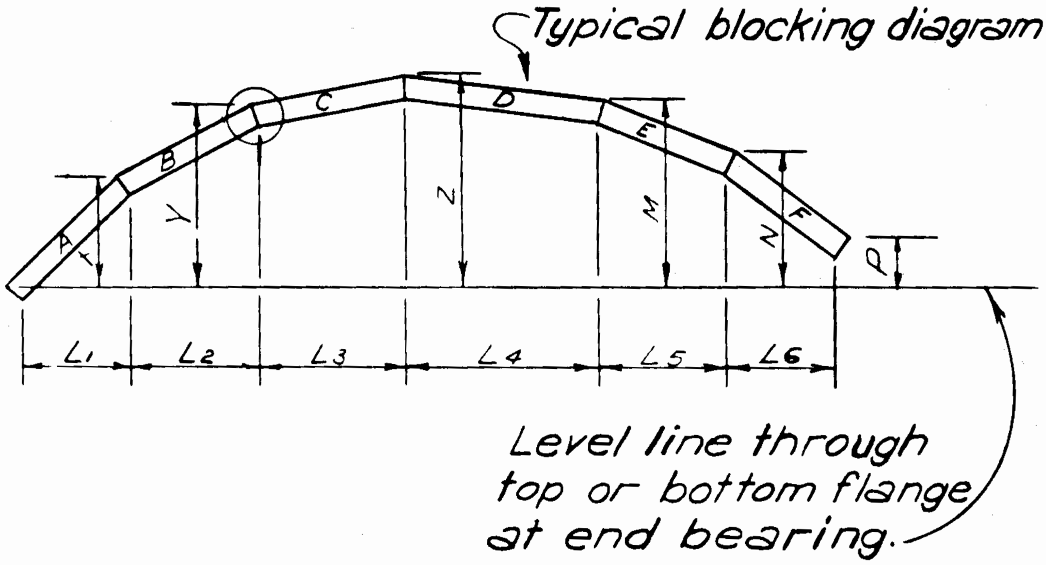


FIG. 15

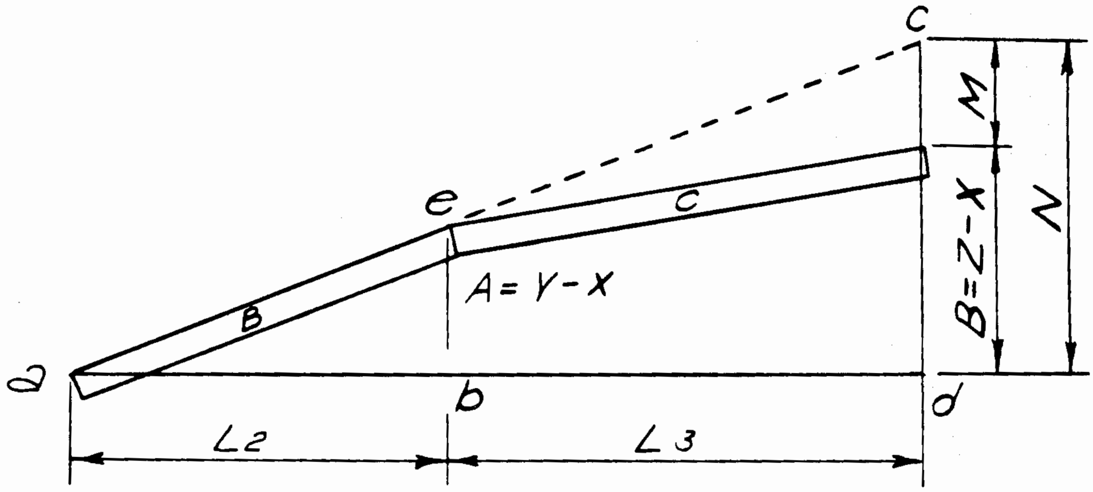


FIG. 16

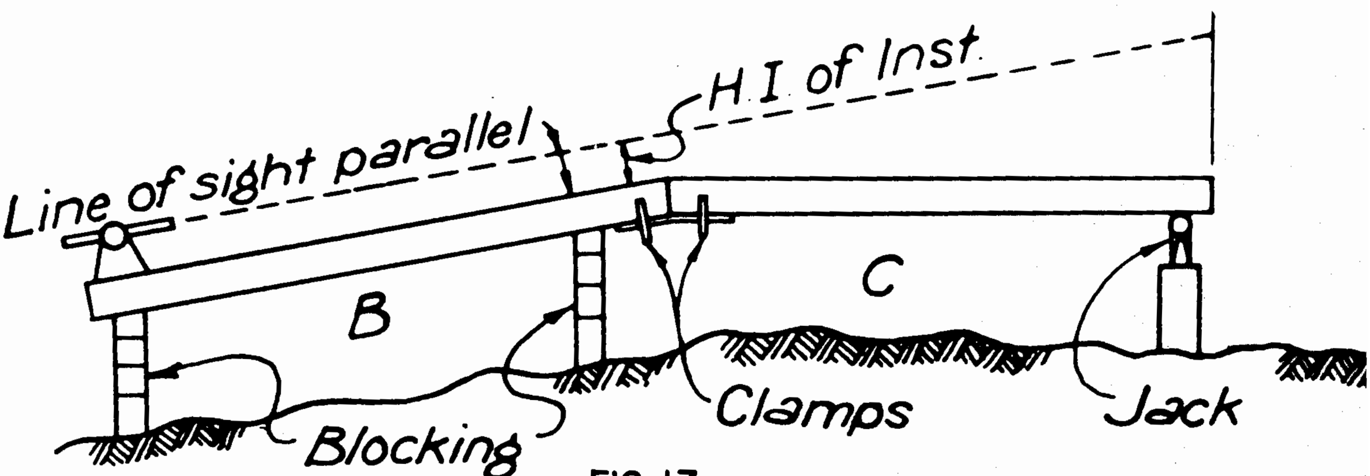


FIG. 17

For example, as in Figure 15, L 5 is equal to 60; L 6 is equal to 49'4½". Dimension P is equal to 4-7/8" and N is equal to 9-3/8", and M is equal to 11½". Referring to Figure 16, A = BE = 9-3/8" - 4-7/8" = 4½" = .375'.

B = 11½" - 4-7/8" = 6-5/8" = .5521'.

Length AB = L 6 = 49.375' and AD = L 5 + L 6 = 109.375

Then DC = N = AD x BC ÷ AB

This = 109.375 x .375 ÷ 49.375 which is .8307'

M = N - B = .8307' - .5521' = .2786' = 3-5/16"

The rest of the operation is a sample field problem. Set a transit up on the end of Beam B and level up. Do not use tripod. Set the base of the transit directly on the beam. (See Figure 17.) Both ends of Beam B are blocked securely. The adjacent of Beam C should be clamped to Beam B with adjustable clamps. Measure up from the flange to the line of sight of the transit, which is a punch mark on each end of the pivot arm of the vertical motion of the transit. Using this dimension, and holding a rule on the other end of Beam B, set the line of sight parallel to the top flange of Beam B by sighting on the ruler. Add the HI of the instrument to Dimension M found in problem above. Adjust far end of Beam C up or down until the rule reading at the end of C is equal to HI plus M. If the beams to be spliced have reverse cambers as in the case when the structure is at the bottom of the vertical curve, the Dimension M would be subtracted from the HI.

The beams do not need to conform with slopes they will have in the structures so long as the relative positions are correctly arrived at by the preceding procedure.

In the above procedure, a level may be used instead of a transit without the tripod. The level may then be set on the end of the beam and a line of parallel sight established as was done with the use of the transit. It will be necessary to set the line of sight by checking several times and adjusting the level scope until it is parallel to the top of the flange. This can be accomplished by taking readings just in front of the telescope and then immediately in front of the splice on the line of sight that is to be parallel.

Other methods of checking the grade may also be used. This procedure is merely one method that may be used. Regardless of the method used for checking beams, they should be checked to insure that the elevations at bearings and splices are in their correct position prior to splicing Unless the blocking rests on very firm soil, the setting of the beams should be checked several times as welding starts to insure against distortion and settlement of the blocking. Space must be provided to enable the welders to complete welding on the bottom side of the bottom flange before the beam is moved.

Welded splices to be made in the air should be held with adjustable clamps so that proper horizontal and vertical setup can be made. (Figures 18, 19, and 20.)

FIG. 18

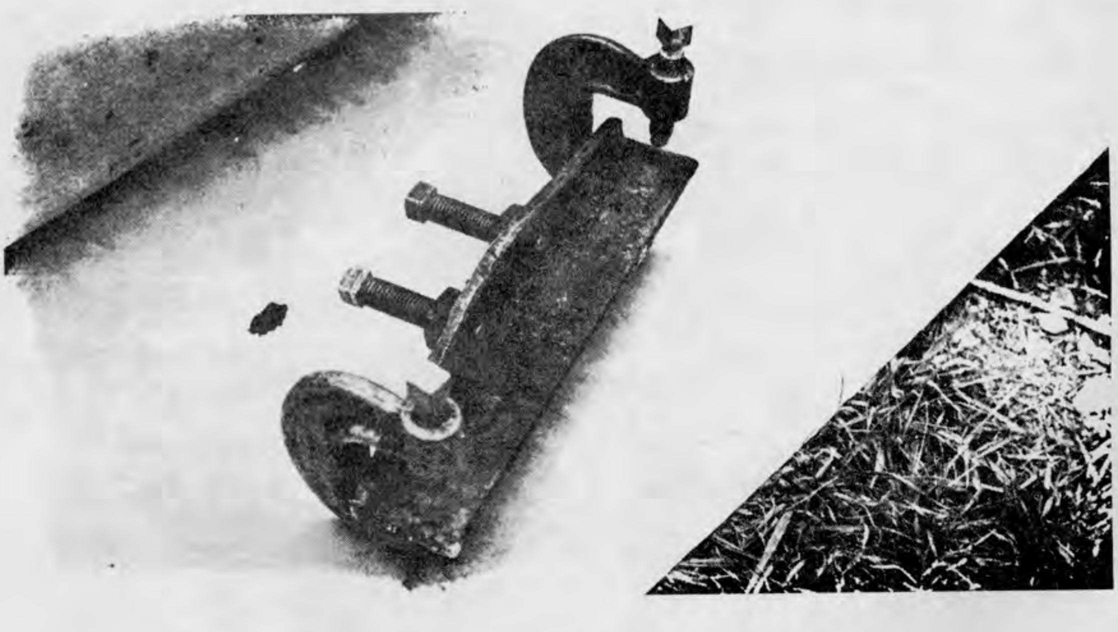


FIG. 19

Proper use of wedges will help in adjustment. Any system of erection that does not provide for adjustment other than manhandling with a pinchbar, etc., should not be allowed.

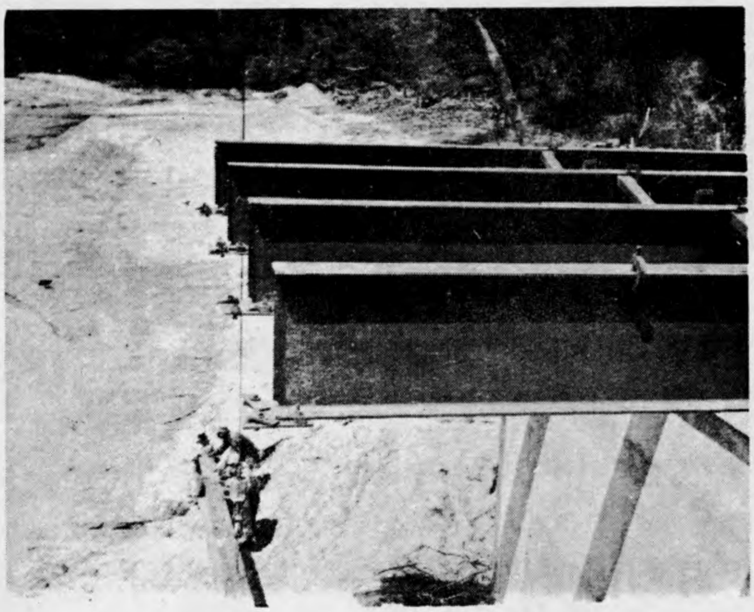


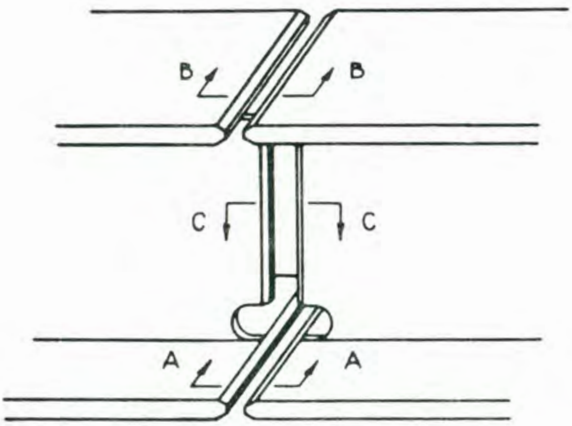
FIG. 20

During welding, proper measures must be allowed to take care of the cooling of the weld metal as it tends to draw the parts closer together. Unless the parts that are welded are free to move, high internal, or locked-in, stresses will be created and the weld may crack. In order to see that this does not happen, the splice must be held absolutely rigid during welding to insure a sound splice except that one beam at the splice should be free to move longitudinally to allow contraction of the weld metal. Beams or girders should not be finally welded to shoes until all splices are made and final position of the unit is checked. In initial stages of erection, beams should be clamped to shoes. All diaphragms which attach to webs of beams or girders should be welded complete before final welding to shoes to allow for shrinkage in the transverse direction.

Laterals and diaphragms should not be tacked to beams until splices are one hundred per cent tight. If part of the system is used to provide lateral stability during erection, they should be clamped, not welded, to beams. Timber or steel may be clamped across the top of beams to provide lateral braces, but reinforcing bars or other steel shapes should not be welded to the beams at any time. The beams or girders should bear one hundred per cent on the shoes. Sometimes, curled or bent flanges prevent this and unless corrective measures are taken, improper bearing stresses result.

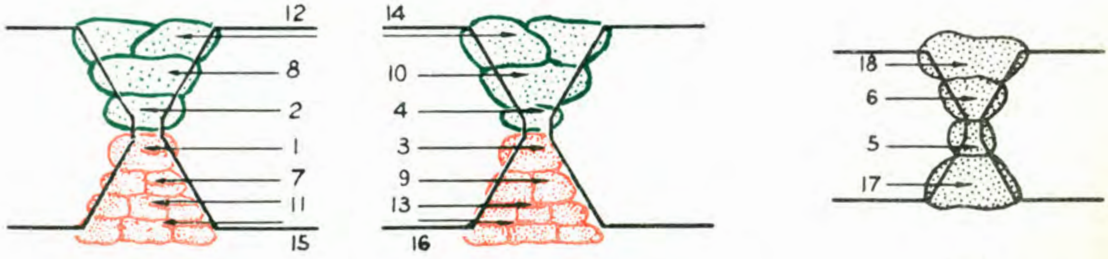
In welding the splices, a definite and approved welding procedure must be adhered to. Better control of shrinkage and distortion and reduction of locked-in stresses is obtained in this manner. Passes should be made symmetrically, if possible, and should alternate from both sides of a double V-joint and from flange to flange. The pass procedure in Figure 21 has proven to be satisfactory and no deviation from this should be allowed the welder. Some smaller-size beams will require fewer passes than shown in this figure. However, the balanced sequence must still be followed.

WELDING PROCEDURE FOR SPLICES



Those beads shown in Red should be in the overhead position. Those shown in Green should be made in the flat position.

Passes 1&2 may be put in the top flange and 3&4 in the bottom flange.



A-A
Bottom Flange

B-B
Top Flange

C-C
Web

FIG. 21

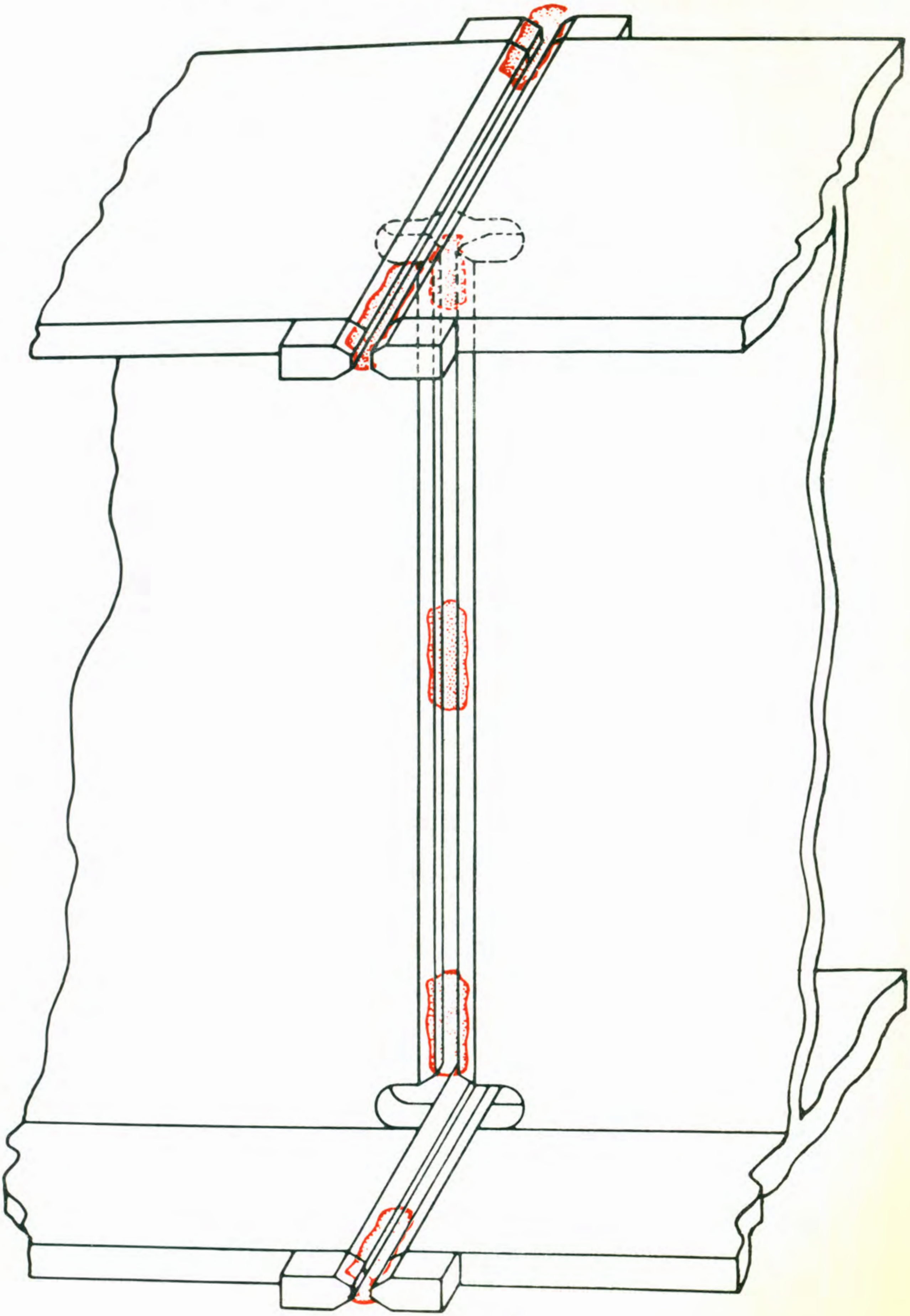


FIG. 22

All welds on flanges shall start or stop on these bars. Bars shall be of mild steel. After the weld is completed, extension bars should be burned off flush and the ends ground down. The fabricator must furnish these extensions as part of the beam or girder fabrication. It is required that these extension bars be put on both beams at the splice on both sides of top and bottom flanges. This requires eight bars per splice. They should be approximately one-inch wide, two-inches long, and of a dimension to match the flange thickness. These extension bars should be put on the beams after the beams have been brought into proper alignment by use of aligning clamps and by tack welding to take out minor inaccuracies between the two beams of the splice. The webs of the two beams to be welded should line up vertically. The center of gravity of both beams should coincide. If they do not, offset both flanges equally. (See Figure 23.)

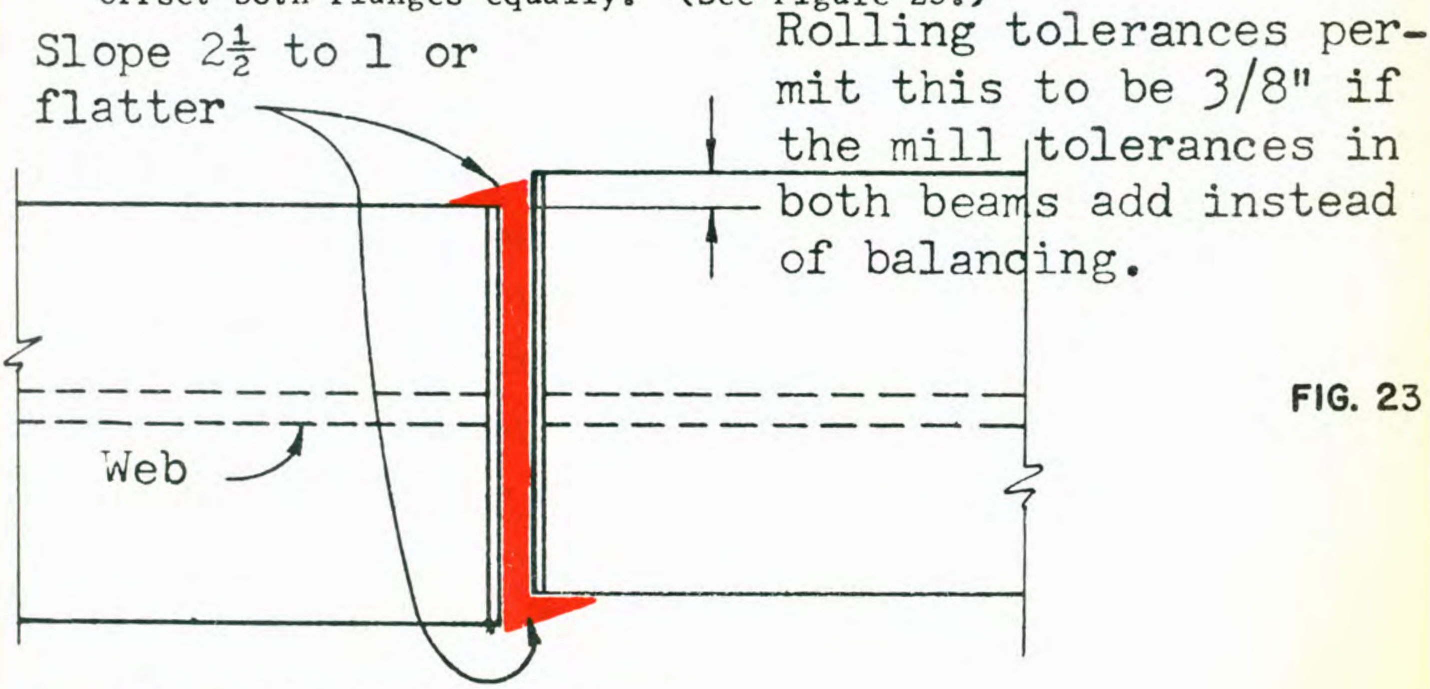


FIG. 23

PLAN VIEW OF OFFSET FLANGES.
NOTE THAT WEBS OF BEAMS <u>ARE</u> ALIGNED

Article 505-K of the AWS specifications requires the use of extension bars for the welding of all flanges on both beams and girders. (See Figure 22.) They should be placed on the flanges, prior to setup and tacking.

The root opening of the splice should have a uniform 3/16th-inch opening for tacking between the webs of the two beams. After tacking, this should leave a uniform 1/8th-inch opening. The dimension shown on the plans for splices shows 1/8th inch plus 1/16th inch minus zero. This is not for field fit-up, but rather for the fabricator's use in dimensioning. The rule of proper fit-up for welding is that after the tack welds have taken their shrinkage, there will be sufficient root opening at the narrowest spot to get complete penetration with the first root pass. The welding should start at the point of the narrowest opening. If a uniform 3/16th opening cannot be obtained, between the webs and the flanges, the beams should be so spaced so that the closest gap at any point is 3/16ths of an inch. Sometimes, by correct tacking, starting nearest the 3/16ths-inch gap and proceeding towards the wider opening, the wider gap will close to approximately the correct opening. If a 3/16ths-inch opening at the narrowest point allows 1/4 inch or more at other points, the wide points on both web and flange should be built up by running a stringer bead along the nose. These build-ups must be allowed to cool before proceeding with the root passes.

In tacking the splices prior to putting on the final passes, three tacks are usually used in the web section with a minimum length of two to three inches. In deeper plate girders, four or five tacks are sometimes used in the web. The webs, of course, should be tacked first. Two-inch tacks, or longer, should then be placed at each end of both flange plates. This procedure must be followed. (See Figure 22.) These tacks will have to be heavy enough and sufficient in length so that when the welder backs up the tack on the opposite side, the heat generated will not allow the webs to move out of alignment. This is particularly true if the webs have had to be moved very much to bring them into alignment. In this case, a tack should be made longer. This procedure applies to the flanges as well as to the webs. The welder should be instructed that while he is welding on the web, all passes should be made by using a back-step sequence and should be made uphill, never downhill. (Figure 24.)

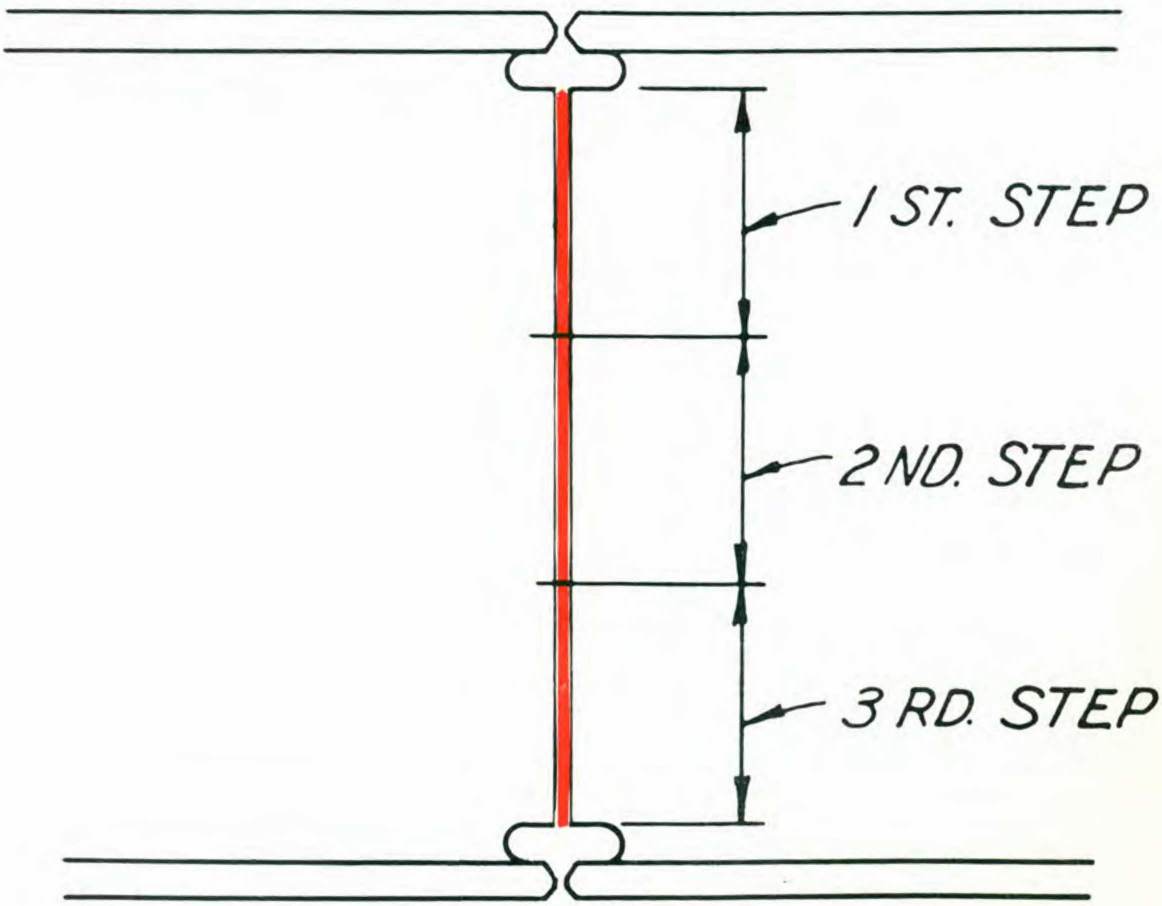


FIG. 24

The weld may be made by either beading or weaving, except that in the overhead position, the welder shall make all passes by beading. When weaving, the width of the pass shall not be greater than twice the size of the electrode being used. Wherever possible, weaving should be used, since maximum ductility of the weld is obtained in this manner.

All root passes on flanges shall be made overhead (tack welds included). The weld will then be chipped out to sound metal from the top and a back-up pass run in a flat position.

Electrodes for welding of beams and plate girders should be of AWS E6010 or E6011 classification, or the low-hydrogen electrodes E7015 or E7016 may be used in lieu of the two previously mentioned. Where a pre-heat is required, the low-hydrogen rod may be used in lieu of pre-heating up to two inches thickness of metal. When the flanges to be welded are over 1-1/4", the low-hydrogen electrodes are required to be used. A color chart for electrode identification is shown in Figure 25.

The welding inspector should give each welder complete instructions regarding the welding procedure prior to his beginning the weld. This consists of type of weld; sequence of welding; type, size, and current range for electrodes to be used; pre-heat, if required; wind and weather restrictions; set-up required, etc. Men who are regularly employed in this type of work and are known by the Inspector will not need to be given this information or checking. New men, however, must have complete instruction.

NEMA standard for electrode identification

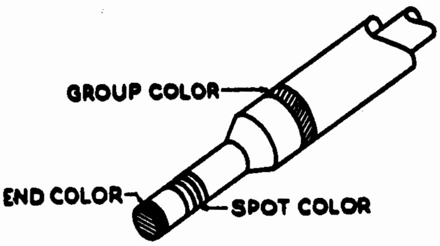


Fig. 1
Location of Color Markings for End-grip Electrodes

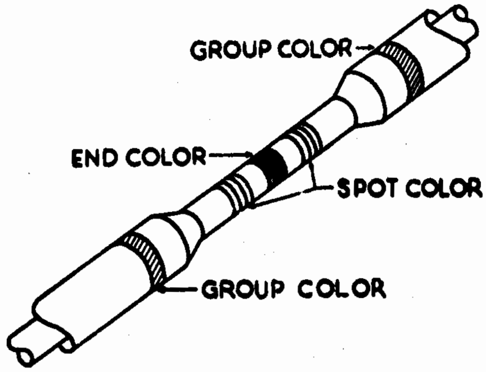


Fig. 2
Location of Color Markings for Center-grip Electrodes

Note: In the case of center-grip electrodes, the spot color will be located on each side of the centrally located end color.

Mild Steel and Low Alloy Steel

AWS GRADES	END COLOR	SPOT COLOR	GROUP COLOR
E-6010	None	None	None
6011	None	Blue	None
6012	None	White	None
6013	None	Brown	None
6015	None	Red	None
6016	None	Orange	None
6020	None	Green	None
6024	None	Yellow	None
6027	None	Silver	None
7010	Blue	None	None
7011	Blue	Blue	None
7013	Blue	Brown	Silver
7015	Blue	Red	Green
7016	Blue	Orange	Green
7020	Blue	Green	Silver
8010	White	None	None
8011	White	Blue	None
8013	White	Brown	Silver
8015	White	Red	Green
8016	White	Orange	Green
8020	White	Green	Silver
9010	Brown	None	None
9011	Brown	Blue	None
9013	Brown	Brown	Silver
9015	Brown	Red	Green
9016	Brown	Orange	Green
9020	Brown	Green	Silver

FIG. 25

The Inspector should check for defects in welding splices and any defects found should be corrected. In general, the weld should be sound, clean metal, free of slag inclusions and porosity. Filler metal should have complete fusion with the base metal and complete penetration of the joints. Both the metals can be observed when being laid in and root passes must be checked for penetration from the backside of the joints by the Inspector. The Inspector should check this with his welding shield as the welder makes the root passes on the tacking up of the joint as well as the completing of the joints. Welds which show slag inclusions, porosity, lack of fusion, penetration, and uneven contour, sagging, or overlapping metal should be gouged out and rewelded. Welds showing undercuts should have small stringer beads running along the toe of the undercut. A smaller electrode should be used for this pass than was used in making the initial weld. Each pass should be completely cleaned of slag before it is covered with another pass. A chipping hammer or descaling tool, wire brush or grinding machine can be used for this. Proper cleaning before welding between all passes cannot be overemphasized. Inspectors should check to see that no craters are left in the weld each time an arc is started to continue a weld. The arc should be struck ahead and then worked back to obtain fusion and prevent craters. If craters are present, they should be filled flush with weld metal. A good welder will fill the craters as he breaks the arc.

No welding should be permitted in rain, snow, or sleet. Moisture from fog or dew shall be driven off by heat before welding commences. This is particularly true in the early morning in the wintertime. Wind will tend to blow the gas shield from around the arc. Protection should be provided in windy weather in the form of adequate windbreaks which will protect the working area from direct wind. (See Figure 26.)

FIG. 26

No welding shall be permitted when air temperature is below zero degrees fahrenheit. If the temperature is above zero degrees, yet is so cold as to hamper the workman in producing sound work, no welding should be allowed.

The alignment and setup of beams, correct root opening, and sound weld metal with proper penetration in the root pass are the most important phases of beam and girder splices. The Inspector should always be present during these operations. If these operations are correct and a qualified welder does the work, there is no reason for a badly welded splice. Inspectors should use their shields and actually observe the weld metal as it goes into the root pass. If the weld does not penetrate completely, the joint should be chipped down to sound metal or gouged out and re-welded. The root pass should be thoroughly cleaned and a careful check made to see if any cracks have developed. A very small crack will progress until it eventually penetrates the complete weld. Any crack, regardless of size, should be gouged out and re-welded. Cracks should be gouged out two inches beyond each end of the crack.

The Inspector should keep a constant check on the size, type, and condition of electrodes. Rods that have dried out and cracked or those that have been rained on or thoroughly wet in any manner should be discarded and not used. Low-hydrogen electrodes packed in hermetically sealed cans must be used within four hours after opening. Those not used in four hours, electrodes in non-hermetically sealed cans, and electrodes exposed for more than one hour to a 75 per cent, or greater, humidity shall be dried for at least two hours at a temperature between three hundred and four hundred degrees before being used.

The Inspector should keep a written record of the welds made on each contract by each welder. He should also see that the welder marks each weld he makes and that any repair work required is done.

Before final acceptance of welding on a job, the Inspector should check and see that all welds have been made that are required by the plans. All fillet welds should be checked with the gauge to be sure that none are undersize or under length. Butt welds should normally have 1/16th-inch reinforcement over the thickness of the splice. Undersize welds, buildups of butt welds in excess of 1/8th inch should not be accepted. All welds, both field and shop, should be checked for proper cleaning, undercut, overlap, poor contours. The welds should be cleaned thoroughly and given three days to set, brushed down, and washed with clean water, dried and then painted.

When the steel beams are placed on the shoes, there are important items that must be checked. First, the beam should be centered on the shoe laterally. Second, it is necessary that the end of the beam be the proper distance from the centerline of bearing. Third, the beam must have full bearing on the shoe.

When all the beams are welded in the span, the diaphragms are located by measuring the required distance along the centerline of the beams. Before tacking any of the diaphragms, the beams should be spaced the plan distance, center to center. This is accomplished by plumbing up with a carpenter's level at the centerline of the bridge and measuring over to the web. These distances should be set at each bent and the two beams positioned. The beams should be clamped to the shoes or tacked the required center-to-center distance. If the beams are straight, then the diaphragms should fit easily into place with the proper gap for welding. If the beams are warped or the flanges tilted, a small amount of pulling or spreading may be necessary to make the diaphragms fit properly and to have the beams aligned properly. Directly over the bearing, the diaphragms should fit properly with no trouble if the beams have been set the proper center-to-center distance. Do not try to align the beams by setting the flanges of the beams on the center of the shoe, as the web of the beam may be off-center of the flanges. That is why it is recommended that the web-to-web distance be checked in setting the beams for alignment.

3. <u>Floor System</u>

a. <u>Inspection and Handling</u>

The diaphragms should be inspected as they arrive on the job to see that they conform to the shop drawings.

They should be stacked on skids and handled in such a manner that the shop code of paint is not marred. They should not be piled on top of each other but should be stacked so that they can be handled and assembled in the structure according to the erection layout. The diaphragms should be placed between the flanges of the beams or girders at the location shown on the erection layout, and clamped to the beam or girder by means of C-clamps. It is not advisable to lay these members between the beams or girders as it might be possible for them to fall through and injure someone or damage the diaphragms. The other items of inspection and handling listed above in Item 2, Welded Steel I-Beams, also apply in general to the floor system.

b. Location of Diaphragms

The location for each diaphragm shown on the erection layout and these positions should be marked on the two outside beams of the structure. The welding contractor can then place a stringline across the two outside beams and below the bottom flange to check the alignment of each diaphragm. After the diaphragm is located in position, it should be tacked. The tacking and locating of the diaphragm should proceed from one end of the structure to the other. It is advisable to tack the construction joint diaphragm ahead of the X-beam braces. The construction joint diaphragm should be tacked in position and should be checked to see that it conforms to plan dimensions before tacking. The welding contractor can then drop back and tack the crossbeam diaphragms in place. The tops of the beams should be checked as well as the bottom to have the proper web-to-web distance before tacking.

c. Welding

As the welding contractor proceeds with the tacking of the diaphragms at the proper location, other welders may start welding the diaphragms that have previously been tack-welded in position. The Inspector should check the fillet welds on these diaphragms to see that they conform to the plan dimension. Any defect should be marked and called to the attention of the welder and it should be corrected before final acceptance of the welding. The Inspector should see that the welder is not allowed to make fillet welds larger than 5/16ths-inch in one pass, except where he is making a fillet weld vertically. In this case, the size made in one pass can be up to a maximum of one-half inch. The Inspector should also see that the maximum thickness of layers made with each pass does not exceed the following: 1/8th inch for subsequent layers of weld made in the flat position; 3/16ths inch for subsequent layers of welds made in the vertical, overhead, or horizontal position. The welder should not use electrodes larger than the specifications permit or that he has been qualified for. Normally, this size will be 5/32nds of an inch, or 3/16ths of an inch.

The Inspector should ascertain that the size, length and location of each fillet weld conforms to the requirements and details of the plans and specifications. He should see that no welds are omitted and no unspecified welds have been added without approval. The Inspector should check the size and contour of all welds with suitable gauges. Visual inspection for cracks in welds and base material and other defects should be aided by strong light or a magnifying glass. The Inspector should identify with a distinguishing mark all welding that has been inspected and accepted. The Inspector should keep a record of all welders and welding operators' qualifications, all qualifications or tests that are made, and any other information that may be required of the Engineer.

The Contractor is expected to comply with all the demands of the Inspector to correct improper workmanship and to remove and replace, as instructed, all defective welds. In the event faulty welding shall so damage the base metal that, in the judgment of the Engineer, its retention is not in accordance with the intent of the plans and specifications, the Contractor shall remove and replace the damaged material or compensate for the deficiency in a manner approved by the Engineer.

VI. Slabs and Curbs

A. Slabs

1. Forms

The forms for various types of bridge deck construction are numerous and require different types of supports. Plans covering forms and falsework for any type of bridge deck that is twenty feet in length must be submitted to the Engineer for review and approval. These plans should show all details of the proposed forms, falsework, and bracing, so that a structural analysis may be made. These plans should be checked in the Residency Office and then submitted to the District Office. After approval of the form and falsework plans, the Contractor can then start construction of his forms. The deck form supports for steel I-beams, plate girders, and prestressed girders are of a similar nature.

Most of the deck supports are needle beams or hanger brackets. For I-beam and plate girder units, the needle beams usually consist of metal jacklegs supporting 2x10 joists on three-foot centers, which support the deck pans. These pans are made in lengths that will fit the diaphragm spacing on the I-beam unit or plate girder unit. They are usually two feet wide, depending on the beam spacing. Pans are usually made in lengths of seven to ten feet. A filler strip is provided at diaphragms and between beam spacings. This permits easy removal of the form supports after the deck has been cured the required time. A similar type of arrangement can be used for prestressed concrete beams; however, the support for the jacks will usually be 4x6's, supported on the lower haunches of the prestressed beams.

Another type of deck support consists of one-half inch round hangers with bolts and plate washers, usually on four-foot centers. These bolts support double 2x10 joists or double 2x8 joists on four-foot centers, or less, depending on the span between adjacent lines of beams. The deck pans are then supported by 4x4's. The hanger spacing will depend on the type of form supports the Contractor uses. If the Contractor uses ledgers running parallel to the length of the beams on which 2x10 jacks are supported, on three-and-one-half-foot centers, the coil hanger spacing might be increased to six-foot centers maximum. Where the coil bolt supports the jacks and deck forms without supporting ledgers, it is necessary to reduce the centers to about three-foot center.

As a sample illustration, suppose the Contractor submits form details showing double 2x6 joists on four-foot three-inch centers with 4x4's on 16-inch centers, with three-quarter-inch plywood decks and the parallel beam spacing is on nine-foot centers. Consider that the deck is six-and-one-quarter inches thick, the load on any two pair of double 2x6 joists would then be 2,950 lbs, since the weight of green reinforced concrete is assumed to be 150 lbs per cubic foot. The forms are then subjected to full fluid pressure for a limited period of time after the concrete is placed. In addition to this load which is treated as dead load throughout this discussion, it is advisable to make allowance for construction loads of men, carts, impact, etc. This allowance is generally considered to be 50 lbs per square foot. The uniform weight per lineal foot on the double 2x6' stringers would then be one foot x .521' x 4.25 x 200 lbs per cu ft is equal to 442 lbs. Assuming that we have a uniform distributed load on a simple beam, the formula for the maximum moment at the center is equal to $wl^2/8$. We have determined that the uniform weight, "w," is 442 lbs per foot. the length of span for design purposes is assumed to be nine feet. The maximum moment at the center of the two 2x6 stringers is then 442 lbs x $9'^2 \div 8$ = 4,470 ft-lbs or 53,700 in-lbs. The section modulus of a 2x6 is $(8.57")^3$. This is from the formula: $S = BH^2/6$ and a 2x6 is 1-5/8" x 5-5/8" dressed. The base is assumed to be 1-5/8" and the height 5-5/8". We can then determine the stress in the extreme fibers of the double 2x6's by the formula: S (or stress) = moment $\div$ the section modulus. The section modulus of the two 2x6's would be 17.07. When this section modulus is divided into the moment which is 53,640 in-lbs, it gives a stress on the extreme fibers of 3130 lbs per sq in. The specifications allow a tension stress

in extreme fibers for No. 1 structural long-leaf pine of 1,600 lbs per sq in. Thus, it can be seen that the double 2x6's are extremely overstressed. To comply with the specifications, the Contractor would have to use stringers of two 2x10's on the same spacing. This would give a stress of 1,100 lbs per sq in (Section Modulus for 2x10 is $(24.44 \text{ in})^3$. Therefore, $53,640 \div 48.88 = 1100$.)
From the preceding, we can see why it is necessary that the Contractor prepare and submit plans for forms and falsework prior to their actual construction. The Engineer, then, has an opportunity to discover any of the structural defects or any weaknesses and offer his recommendations for improvement, before the Contractor has incurred too great an expense.
Many of the details of form construction can be judged only by practical experience and these are the Contractor's responsibility. The size and spacing of structural members can be checked by mathematical analysis, also, the resistance and bending, shear and compression, and the resulting flexural load ascertained. This analysis should be of vital concern to the Engineer, inasmuch as the deflection of the form section has a direct result on the final appearance of the structure.

The Inspector should see that the lumber used for the deck forms and stringers is free from loose or unsound knots, knotholes, twists, shakes, decay, and other imperfections which will affect its strength or impair the finished surface of the concrete.

All studs and sheathing should be S2E or better. In general practice, the grades of lumber purchased for use in the construction of forms for concrete will be lower than that used for permanent construction. Thus, the allowable stresses as established for concrete form design will be for material of the following grades or equal: Stringers - No. 1 or square-edge and sound yellow pine; studs, waling, and sheathing - No. 2, reasonably clear and sound. Properties of standard board, plank and timber most frequently used in concrete form construction are given in the table on the following page and the properties of the various thicknesses of plywood are shown in Figure 27.

PROPERTIES OF DOUGLAS FIR PLYWOOD
(Grain of face plies parallel to span)

Thickness	Moment of Inertia (for 12" width)	Section Modulus
5/16" (3 equal plies)	0.029	0.186
3/8" (3 plies @ 1/8")	0.051	0.270
1/2" (3 ply)	0.090	0.360
5/8" (5 ply, 1/11", 1/3", 3/16", 1/8", 1/11")	0.167	0.535
3/4" (5 ply)	2.250	0.667
1" (7 plies @ 1/7")	0.713	1.426

Note: When the grain of the face plies is across the span the allowable loads will be smaller than those determined from the above figures as follows:

For 1/2" thickness use 40% less load
For 5/8" thickness use 50% less load
For 3/4" thickness use 75% less load
For any given span or deflection

FIG. 27

TABLE II

PROPERTIES OF STANDARD BOARD, PLANK AND TIMBER
USED IN CONCRETE CONSTRUCTION
DRESSED S4S

Nominal Size in Inches b h	Dressed Size in Inches b h	Area of Section A=bh Sq. In.	Moment of Inertia $I=(\frac{bh^3}{12})$	Section Modulus $S=(\frac{bh^2}{6})$	Weight in Lbs. per Lin. Ft. of Piece
4x1	3 5/8x25/32	2.83	0.14	0.37	0.80
6x1	5 5/8x25/32	4.40	0.22	0.57	1.20
8x1	7 1/2x25/32	5.86	0.30	0.76	1.60
10x1	9 1/2x25/32	7.42	0.38	0.97	2.10
12x1	11 1/2x25/32	8.98	0.46	1.17	2.50
4x1 1/4	3 5/8x1 1/16	3.85	0.36	0.68	1.10
6x1 1/4	5 5/8x1 1/16	5.98	0.56	1.06	1.70
8x1 1/4	7 1/2x1 1/16	7.97	0.75	1.41	2.20
10x1 1/4	9 1/2x1 1/16	10.09	0.95	1.79	2.80
12x1 1/4	11 1/2x1 1/ 6	12.22	1.15	2.16	3.40
4x1 1/2	3 5/8x1 5/16	4.76	0.68	1.04	1.30
6x1 1/2	5 5/8x1 5/16	7.38	1.06	1.62	2.10
8x1 1/2	7 1/2x1 5/16	9.84	1.41	2.15	2 70
10x1 1/2	9 1/2x1 5/16	12.47	1.79	2.73	3.50
12x1 1/2	11 1/2x1 5/16	15.09	2.17	3.30	4.20
4x2	3 5/8x1 5/8	5.89	1.30	1.60	1.63
6x2	5 5/8x1 5/8	9.14	2.01	2.48	2.53
8x2	7 1/2x1 5/8	12.19	2.68	3.30	3.38
10x2	9 1/2x1 5/8	15.44	3.40	4 18	4.28
12x2	11 1/2x1 5/8	18.69	4.11	5.06	5.18
2x4	1 5/8x3 5/8	5.89	6.45	3.56	1.63
2x6	1 5/8x5 5/8	9.14	24.10	8.57	2.53
2x8	1 5/8x7 1/2	12.19	57.13	15.23	3.38
2x10	1 5/8x9 1/2	15.44	116.10	24 44	4.28
2x12	1 5/8x11 1/2	18.69	205.95	35.82	5.18
3x4	2 5/8x3 5/8	9.52	10.42	5.75	2.60
3x6	2 5/8x5 5/8	14.77	38.93	13.84	4.10
3x8	2 5/8x7 1/2	19.69	92.29	24.61	5.47
3x10	2 5/8x9 1/2	24.94	187.55	39 48	6.93
3x12	2 5/8x11 1/2	30.19	332.69	57 86	8.39
4x4	3 5/8x3 5/8	13 14	14.39	7.95	3.64
4x6	3 5/8x5 5/8	20.39	53.76	19.11	5.65
4x8	3 5/8x7 1/2	27.19	127.44	33.99	7.55
4x10	3 5/8x9 1/2	34.44	264.44	54.53	9.57
4x12	3 5/8x11 1/2	41.69	459.43	79.90	11.58
6x6	5 5/8x5 5/8	30.25	76.25	27.73	8.38
6x8	5 5/8x7 1/2	41.25	193.36	51.56	11.43
6x10	5 5/8x9 1/2	52.25	392.96	82.73	14.47
6x12	5 5/8x11 1/2	63.25	697.07	121.23	17.52

The contract plans for our steel bridges show by diagram the deflections which are expected to take place as a result of adding the weight of the slab and railing to the steel structures. On all except the very short simple spans, the concrete deck is placed in short sections and in the sequence shown on the plans. With the placing of each section of the slabs, some deflection takes place in every part of the structure. This occurs in each span of a continuous unit on which concrete is being placed. It is, therefore, necessary to establish a reference datum for setting each header before any slab concrete is placed on the unit. The following routine is suggested for establishing the headers for each pour:

a. Compute the planned elevation of top of concrete for each stringer (or girder) at every proposed construction joint of the slab.

b. Run levels and determine the actual elevation of steel at each stringer (or girder) at every proposed construction joint of the slab.

c. Refer to the table of deflections for dead load of concrete and rail which is shown on the plans. Correct the values found in (b.) above to show the elevations which the steel would have after the concrete slab is completely placed.

d. Compare the profile represented by the (a.) values with the profile represented by the (c.) values. If the differences indicated are too great to provide a normal form setting, or are so small as to result in deficient slab thickness, the profile represented by Step (a.) should be adjusted.

e. Subtract the elevations determined by Step (c.) from the elevations determined by Step (a.) as calculated or adjusted for each point on the beam. These are the values to be used in setting the headers at the construction joints.

These values are then marked on the top of the beams and the carpenters and inspectors work from them. No more running of levels is necessary except as may be necessary to check the top of curb lines from the beam at the same construction joint. The points marked on the steel structure are the reference points. (See Figure 28.)

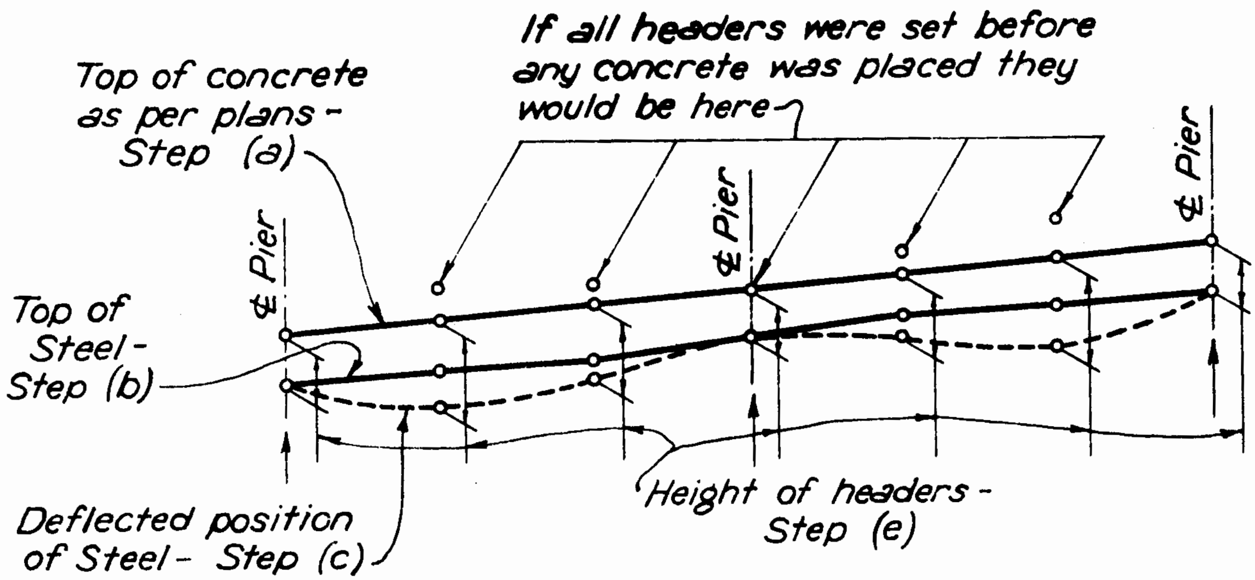


FIG. 28

To secure good lines and grades on the concrete deck of the bridge, great care must be given to all details. After the structural steel beams have been set and the diaphragms welded, line and grade points are then placed on the beams to control the alignment and grade of the concrete deck. From survey points, previously placed on the concrete caps, tangents or concentric lines can be established on the outer steel beams, which are a definite distance from the outside edge of the bridge deck. At construction joints, a steel punch mark is placed at the exact position of the joint. At expansion joints, punch marks should be placed on a line six inches from the end of the steel beam. After the Contractor has placed his forms for the bottom of the deck, the concrete edge can be set exactly by measuring from the punch marks on the steel beams and points established for grading the concrete deck.

Grade points for the future deck construction should be placed near each construction joint and expansion joint so that the headers and armor joints can be set to exact grade. These grade points consist of paint marks with an identifying number painted on the steel beam. Grade points near construction joints should be placed on the side of the joint that will not be covered by the first concrete pour. Grade points should be set for each deflection mark shown on the deflection diagram. It is essential that a very accurate elevation to a thousandth of a foot be taken and recorded for each grade point, particularly at the headers. These elevations should be run by the most experienced crew that the Engineer has and in weather that will permit the taking of very accurate elevations. It is these elevations that are used in the method outlined previously to calculate the cuts and fills which are then painted on the steel beams alongside the grade points. The amount of fill or cut at any given point is the difference between the actual elevation of the point on the steel beam and the theoretical finished concrete grade at the same point. The only place that the grade point will not have to take the dead load deflection of the beam into account is where the grade point is directly over a pier or an abutment. After these correction fills have been computed and checked, they should be painted on the steel beam near the grade point.

Using the fills and stringlines between grade points, the Contractor is able to grade the bottom deck form across the bridge to provide for the correct thickness of the concrete slab.

2. <u>Railing Anchor Bolts</u>

On continuous I-beam units, or simple I-beam spans, the center of each anchor bolt group for the railing should be measured and a center punch mark made on the outside beams of the structure. These marks should be placed on the beams at the same time the location of construction joints are placed. It is necessary that these points be those that are shown on the approved shop drawings furnished by the fabricator of the railing. The rail post spacing should be checked to see that it conforms to the plans and the plans should be checked to see that the rail post spacing will fit the unit in question. This is a very important item, particularly in the case of continuous I-beam units or continuous plate girder units, since the slab will be placed intermittently and the anchor bolts for the railing will have to be placed at the time the deck is poured. It is a difficult matter to try and locate anchor bolt positions each time. Therefore, it is necessary that the entire unit be spaced out accurately prior to beginning concrete pouring. From these marks, carpenters can then square over to the position of the curb forms and locate the railing bolt holes. Plans should be checked to see that the rail posts will not fall at the construction joints. This item should be checked prior to the actual fabrication of the railing, and if any discrepancies are noted, they should be brought to the attention of the Resident Engineer, who, in turn, will notify the District Office. A new rail post spacing should then be arrived at in order to avoid placing a rail post at a construction joint. This information can then be supplied to the Contractor and his fabricator before actual fabrication of the railing begins. This item applies to any type of slab construction, whether it is a concrete slab on I-beams, plate girders, concrete girders, widening, etc.

3. <u>Headers</u>

The headers at construction joints and armor joints are set to exact grade, using the fill that has previously been established and painted on the steel beams. These headers, in addition to being set to correct elevation, must be placed to conform to the grade of the finished concrete slab at that point. Headers at construction joints should be made of a material that will conform to the grade of the finished concrete slab at every point without depressions or sags. The best type of material for this header is usually a heavy steel angle that is attached to another element that is welded to the steel beams at each stringer or each concrete beam. These adjustments or elements will permit the setting of the correct height of the header at each beam and header. The header, itself, should be rigid enough to span between each stringer without deflection. Soft timber should not be used for headers unless they are faced with metal.

Whatever type header is used, it should be set to accurate grade and crown before placing the concrete and checked after placing to see that it remains in the proper position and has the proper crown and elevation. In some cases, when the header is an armor joint, the fabrication of the armor joint should be checked to see that it conforms to the crown of the roadway and if there are discrepancies, they should be corrected before the concrete is placed. This can be done by grinding the highspots or welding places that are low and regrinding to the correct grade.

4. Pouring and Finishing

The specifications state that concrete in superstructures shall be placed in longitudinal strips; placing preferably shall be started at a point in the center of a span adjacent to one curb and the longitudinal strip thus started shall be completed by depositing concrete uniformly in both directions toward the end of the span. The width of longitudinal strip shall be such that the concrete in any strip will not take its initial set before the adjacent strip is placed. The concrete in the curb shall be placed in proper sequence to be monolithic with the adjacent longitudinal strips of the slab. On steep grades, it might be preferable to start at the lower point adjacent to one curb and pour the longitudinal strips from one end to the other.

As soon as the concrete has been placed and vibrated in a longitudinal section of a sufficient width to permit working, the surface shall be approximately leveled and struck off, screeded, and tamped with a longitudinal screed. The screed shall be of such design as to provide the rigidity necessary to hold to true shape and shall have sufficient adjustment provided for such camber that is required. This screed, used for striking off the concrete in the slab, must be set and checked prior to placing the concrete. The camber set into the screed should be such as to take care of the shrinkage and settlement of the concrete after the screed has been removed and an amount equivalent to the vertical curve added for the length of bridge deck being finished. The mid ordinate at the center of the screed should be .005 thousandths of a foot per ten foot of screed to allow for concrete settlement and shrinkage plus the amount of the mid ordinate for the vertical curve in the length of the screed. This vertical curve mid ordinate would only have to be taken into consideration on structures that have long vertical curves that are on grades of 3½% or greater. Screeds should be set on blocks, supported at each end, and a piano wire stretched tightly from end to end. A parabolic curve should then be set in the bottom of the screed, measuring from the piano wire at each adjusting screw. After these ordinates are set, a visual inspection should be made to see if the desired results have been obtained. Screeds should be moved forward across the concrete with a combined longitudinal and transverse motion with the ends resting on the headers or armor joints set true to the roadway grade or on the adjacent finished slab. A slight excess of concrete should be carried ahead of the screed to assure that all those spots are filled with concrete.

The surface of the concrete should be screeded and tamped a sufficient number of times (never less than three) and at such intervals to produce the uniform surface, true to grade and free of voids. There is always a tendency to remove the screed from the slab too quickly which is detrimental to the quality of the riding surface. There is also a tendency to use light screeds to float the slabs thus making it impossible to tamp the concrete deck sufficiently since the screed is so light, the camber will be removed by the tamping action. Where this type of screed is permitted, it will be necessary to screed the deck more times than would be required with a heavier screed that would tamp and cut the deck to the required grade. There is also a tendency, when the lighter type screed is used, to place a higher slump concrete so the screed will cut to the rquired grade more easily.

The specifications state that for spans over forty feet in length, they may be screeded in two or more sections if suitable intermediate templates are installed and if adequate equipment is provided. The templates referred to shall be of such design as to permit their early removal in order to avoid construction joints and to permit satisfactory finishing at and adjacent to the site of the removed template.

Following the screed, the surface should be worked to a smooth finish with a long-handled wood or metal float the proper size or be hand floated from bridges over the slab.

After the floating operation and while the concrete is still plastic, the Contractor shall check the surface with a long-handled ten-foot straightedge. Checks should be made with a straightedge parallel to the centerline. Each pass of the straightedge should lap one-half the preceeding pass. All high spots should be removed and all depressions over one-sixteenth inch in depth should be filled with fresh concrete and refloated. This checking and floating shall be continued until the surface is true to grade and free from depressions, high spots, voids, or rough spots. This seems to be one of the items most Contractors want to delete from the construction procedure. The Inspector should be present at all times when all this is going on and he should watch to see that the straightedge man fills all voids and cuts all high spots. He should be particularly attentive where the straightedge man is working at an armor joint or construction joint, as this is the place where depressions are most numerous.

After straightedging the slab, while the concrete is still plastic and all corrections have been made in the surface, the surface should then be given a belt finish. This belting should be done parallel to the centerline. It should not be permitted when the concrete is too wet. If the concrete is too wet, it has probably been placed with a high slump and, in addition, the concrete will probably slump due to the final belting if it is done while it is too plastic.

After the concrete has attained its final set, the roadway surface shall be tested again with a standard ten-foot metal straightedge and corrections, if necessary, shall conform to the following: straightedge shall be placed parallel to the centerline of the road so as to bridge any depressions and touch any high spots; ordinates measured from the face of the straightedge to the surface of the slab shall not exceed one-sixteenth inch per foot from the nearest point of contact and the maximum ordinate shall not be greater than one-eighth inch. The surface shall be corrected by grinding off the high spots as may be required in order to conform to these limits.

This is another item that most Contractors tend to try to eliminate from their construction procedures, and it is the duty of the Inspector to see that these items are completed before the Contractor leaves the work for that day.

In the case of concrete slabs or girder spans on falsework, or floor joists, the floor should be finished so as to provide a camber sufficient to offset dead load deflection of the span. Other spans shall be so finished as directed by the Engineer.

B. Curbs

I. Forms

Our bridge contractors are generally using metal brackets for support of forms for slab overhangs where needle beams were formerly used. This applies to I-Beam units and plate girder units, in particular. On prestressed concrete structures, the contractors are generally providing three types of forms for supporting the slab and curb overhangs. These consist of needle beams, wooden overhang brackets and steel overhang brackets. Metal brackets when properly detailed and used, are superior to the needle beam or wooden overhang brackets.

There are many types of these brackets and each type must satisfy certain design requirements. These metal brackets have one feature in common. They attach temporarily to the stringer or girder by means of a bolt which passes through a hole in the web. Where these holes are placed in continuous I-Beam units or plate girder units, they should be uniformly spaced and of a uniform size. Some contractors have the holes put in the beams by the steel fabricating plant before they are delivered to the project. Other contractors prefer to drill the holes in the field. Some contractors wish to burn the holes full-size in the field. This is not a satisfactory method. Satisfactory results can be obtained if the holes are burned not larger than one-half inch in diameter and then reamed to full size, thus removing all of the burned metal and leaving a square-edge hole and sound metal. This last method is generally more costly to the Contractor and more worrisome to the Engineer who intends to have good workmanship evidenced by appearance of the finished job.

The first brackets used were built for a certain depth of stringer. (Figure 29.) They attach by bolt near the top flange and occupy the full depth of the stringer. Two sets of screws at the bottom permit adjustment at the outer end of the bracket. These brackets when loaded, put a twisting force on the stringer which conveys this force to the flanges, which, in turn, conveys to the diaphragm, which resists these forces. Where the brackets are located very close to the diaphragm, very little stress is carried by the flanges of the stringers. Where the bracket is located midway between diaphragms, the flange stresses can be high within the allowable limits. The factors which affect these flange stresses of this particular type of bracket are:

(1) Amount of slab overhang

(2) Spacing of brackets

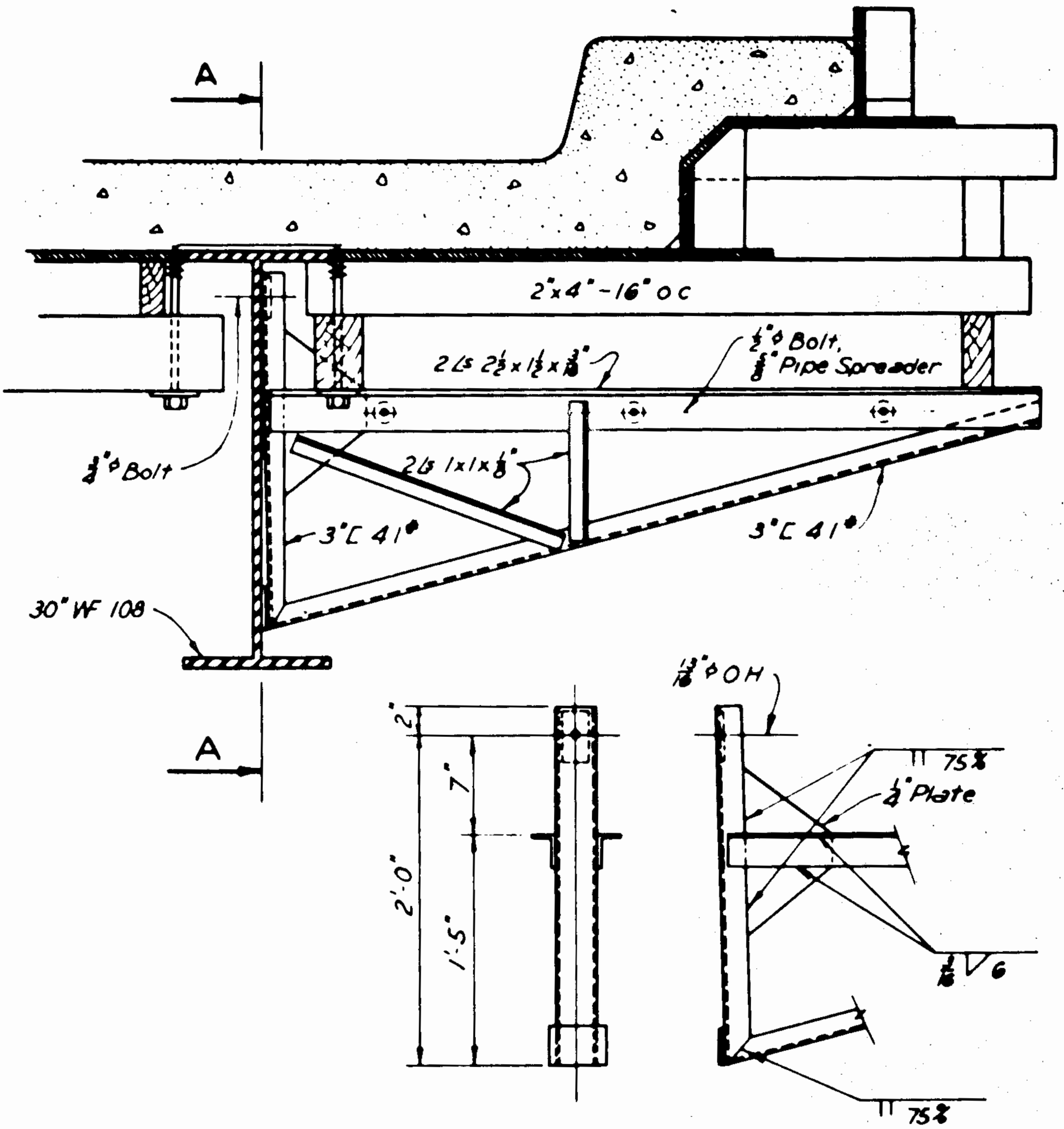
(3) Spacing of diaphragms

(4) Unit weight of slab concrete

(5) Arrangement of construction walks

Where contractors wish to use the same size bracket on all size I-beam stringers, different stress patterns are set up. A contractor who has a bracket which is well-adapted to use on a thirty-six inch wide flange, 150-lb beam, with a web thickness of 5/8" may overstress a girder if it is installed on a 3/8" thick web. A particular bracket that is satisfactory for use on one bridge with certain size stringers and a certain diaphragm spacing may not be satisfactory for use on another bridge where different conditions occur.

It is for this reason that it is wise to check this particular feature of the Contractor's form details well in advance of the actual beginning of form building.

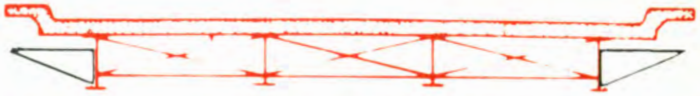


SEC. A-A

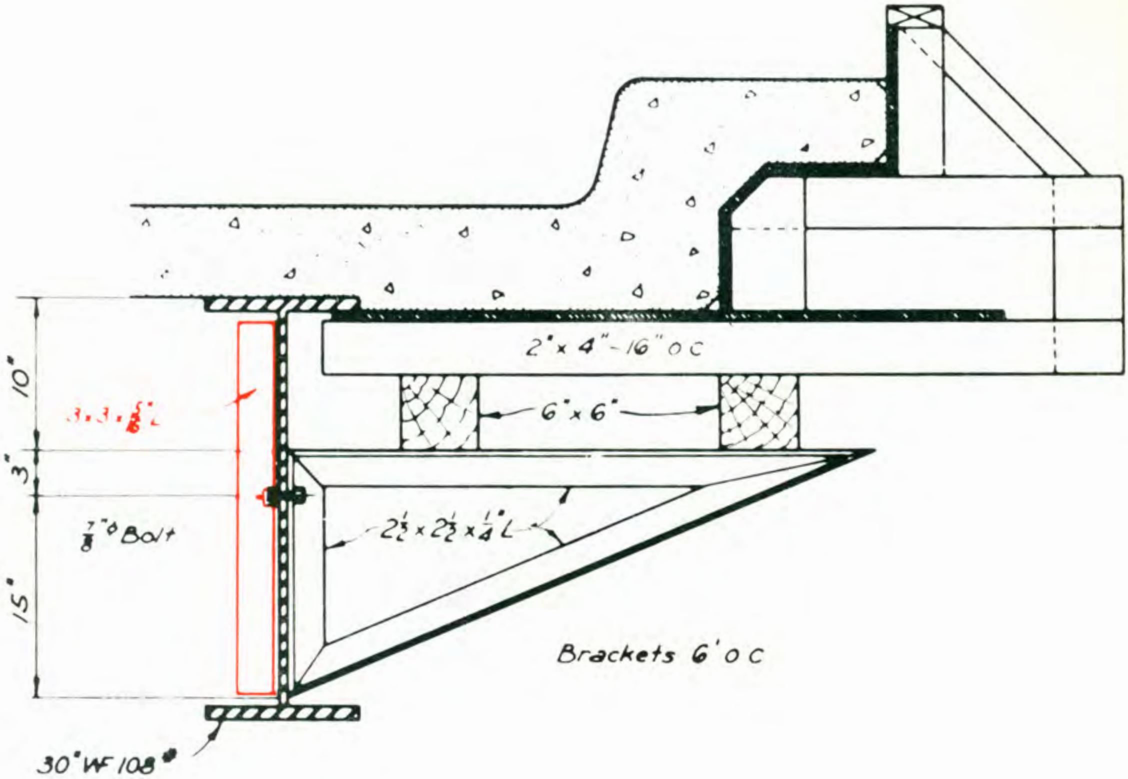
This bracket brings its load close to the flanges, therefore needs no back-up angle. This design is satisfactory without any change.

OVERHANG SUPPORT BRACKET

FIG. 29



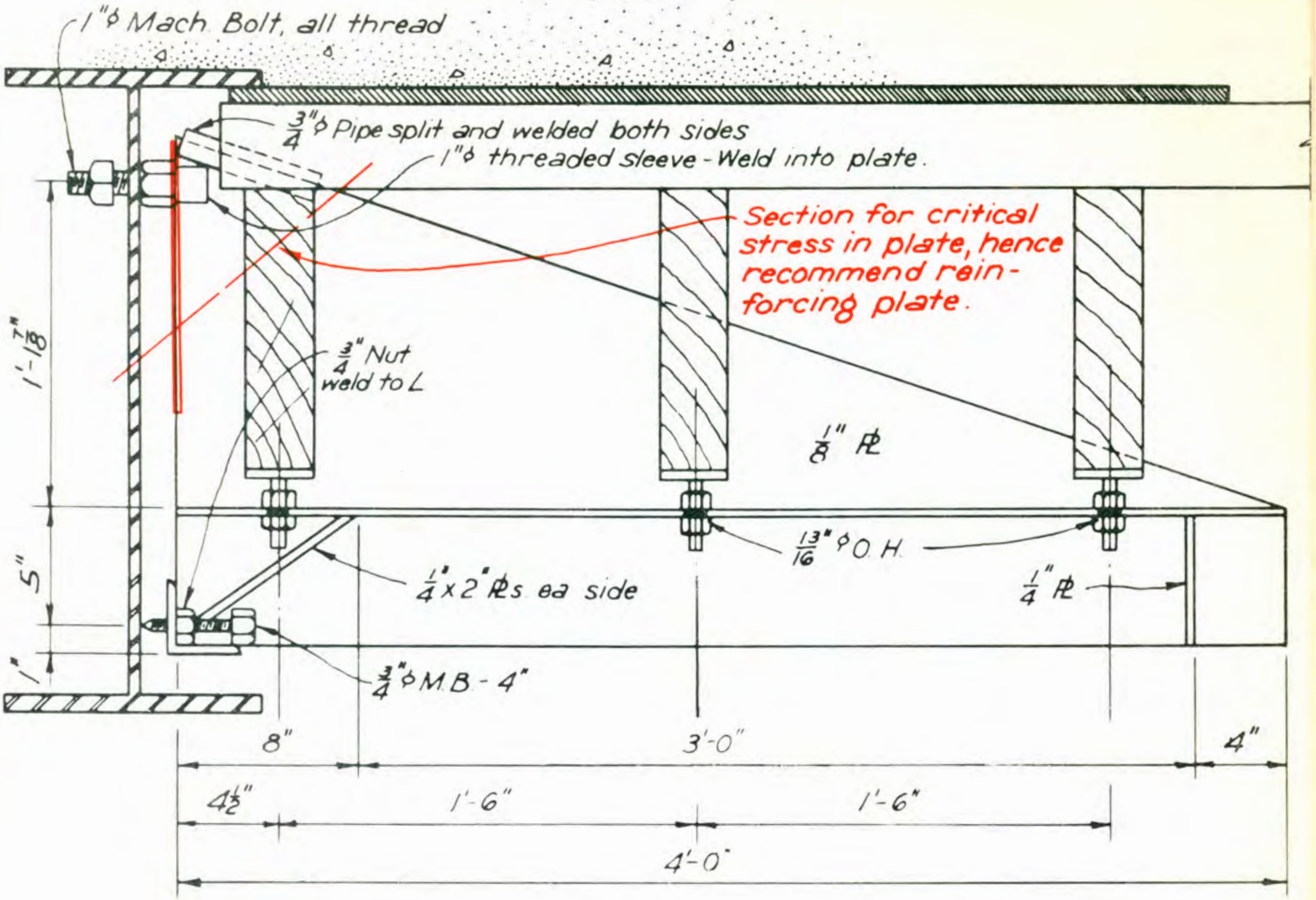
MANNER OF USING OVERHANG BRACKETS

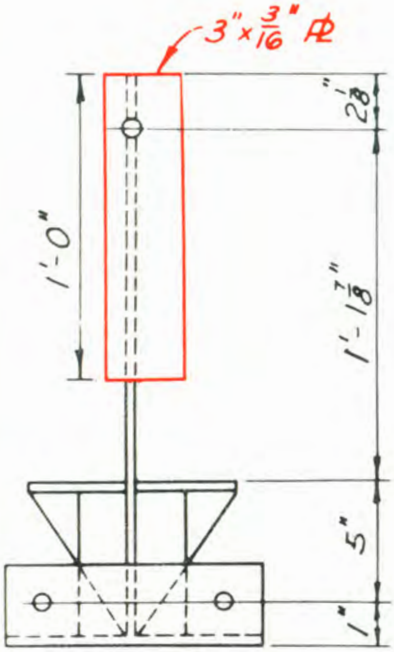


This bracket produces a heavy load on the center of the web of the 30" WF 108 beam and may overstress it. To overcome this condition a 3 x 3 x 5/16" L, (shown in red), is used, in the vertical position to take the load from the bolt and to transfer half of it to the top flange and half to the bottom flange.

OVERHANG SUPPORT BRACKET

FIG. 30

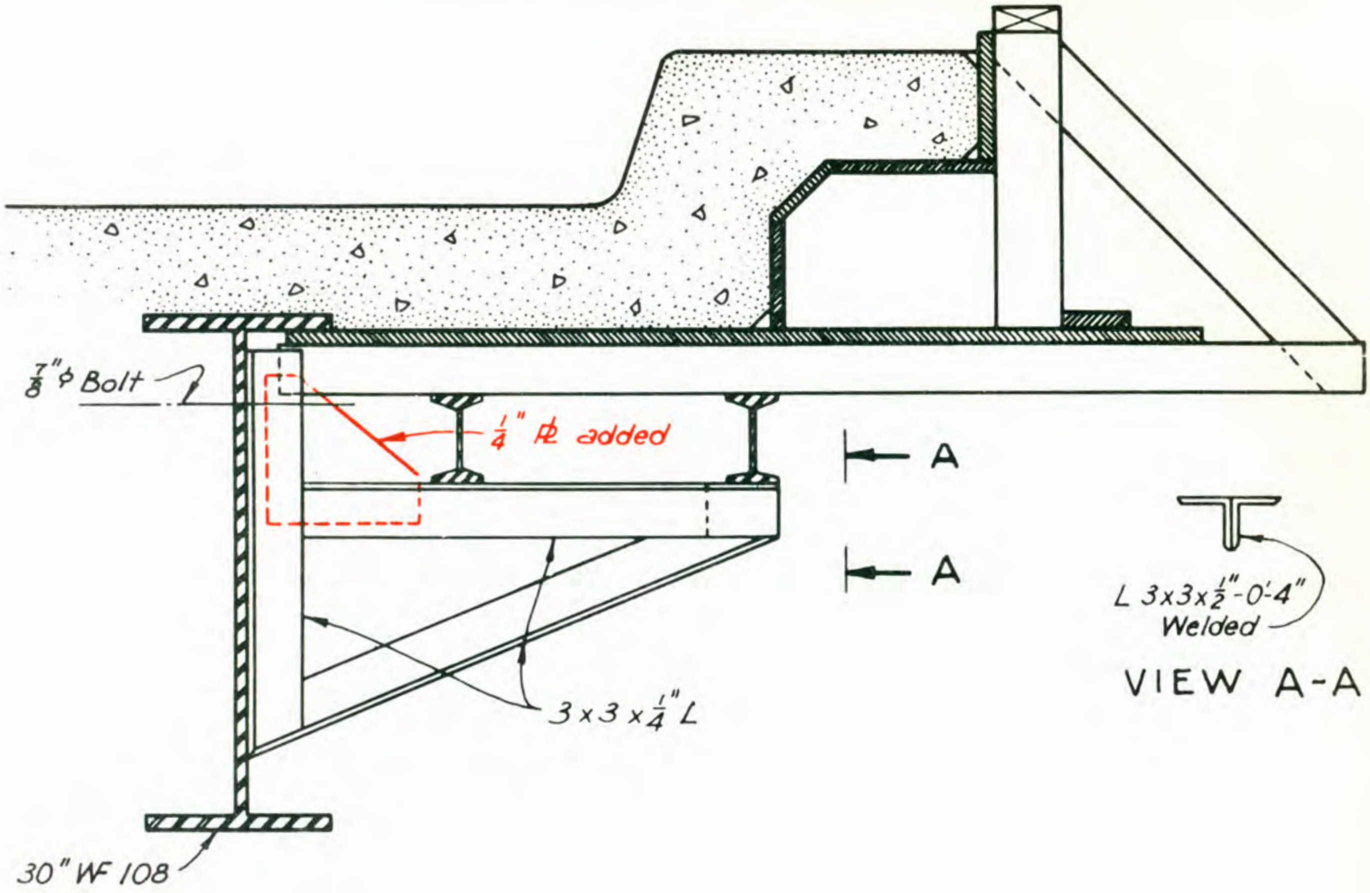




This bracket has been used on both rolled beams and plate girders. When used on plate girders and when located more than 6 inches from a diafram or stiffener, a back-up angle is required at the bolted connection in the web of the girder. A desireable strengthening detail is shown in red.

OVERHANG SUPPORT BRACKET

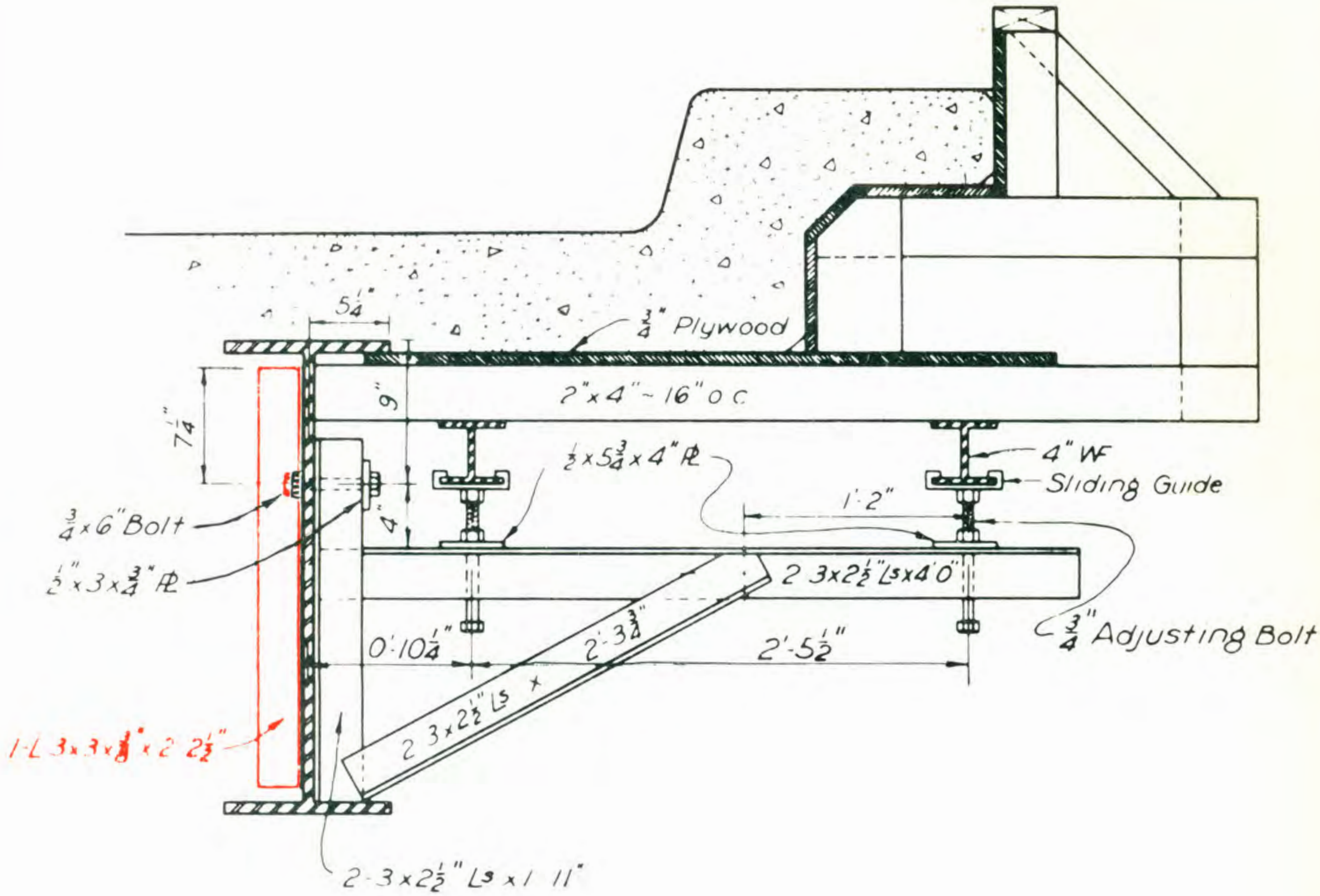
FIG. 31



This bracket, as submitted by the contractor, required a reinforcing plate, (shown in red) to transfer stress from the horizontal angle to the vertical angle.

OVERHANG SUPPORT BRACKET

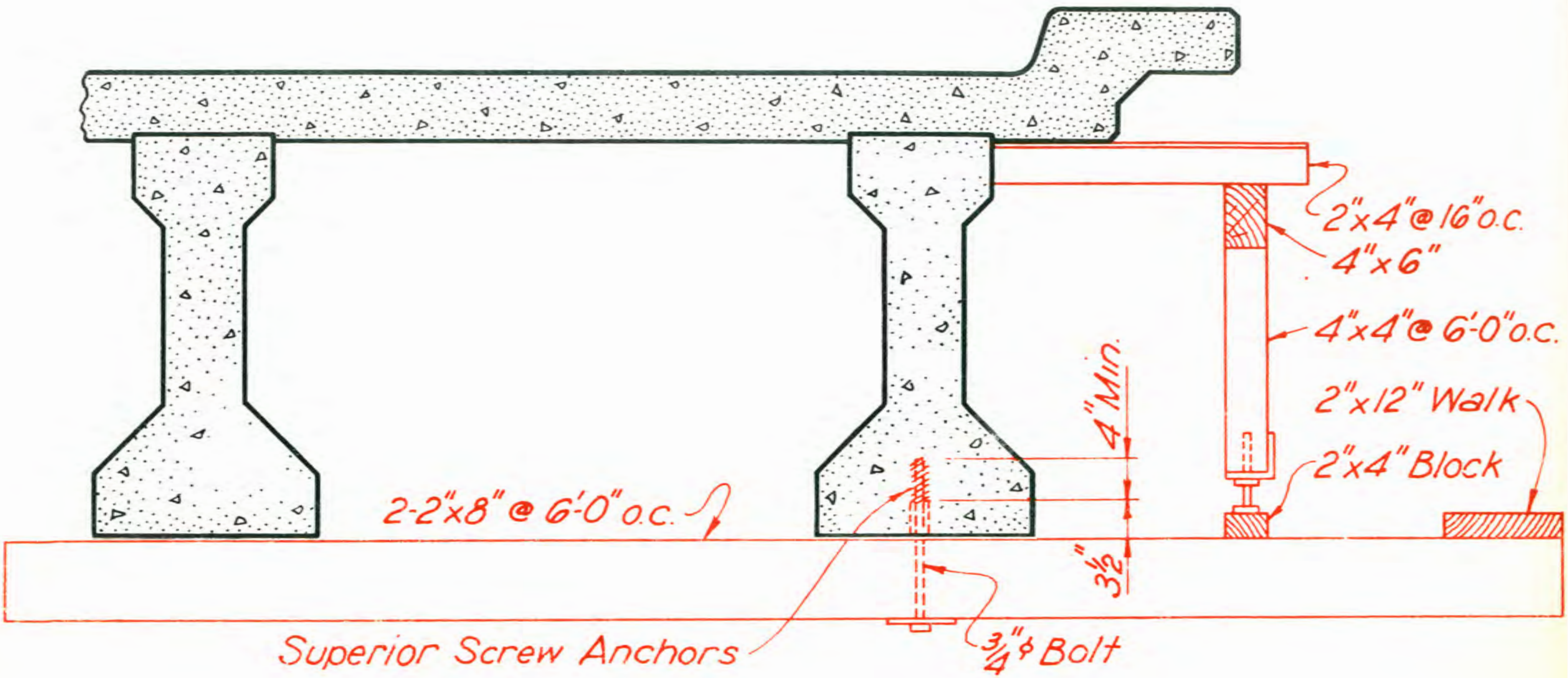
FIG. 32



Another bracket which needed the addition of an angle, (shown in red), on the back side of the stringer web to distribute the load from the bolt.

OVERHANG SUPPORT BRACKET

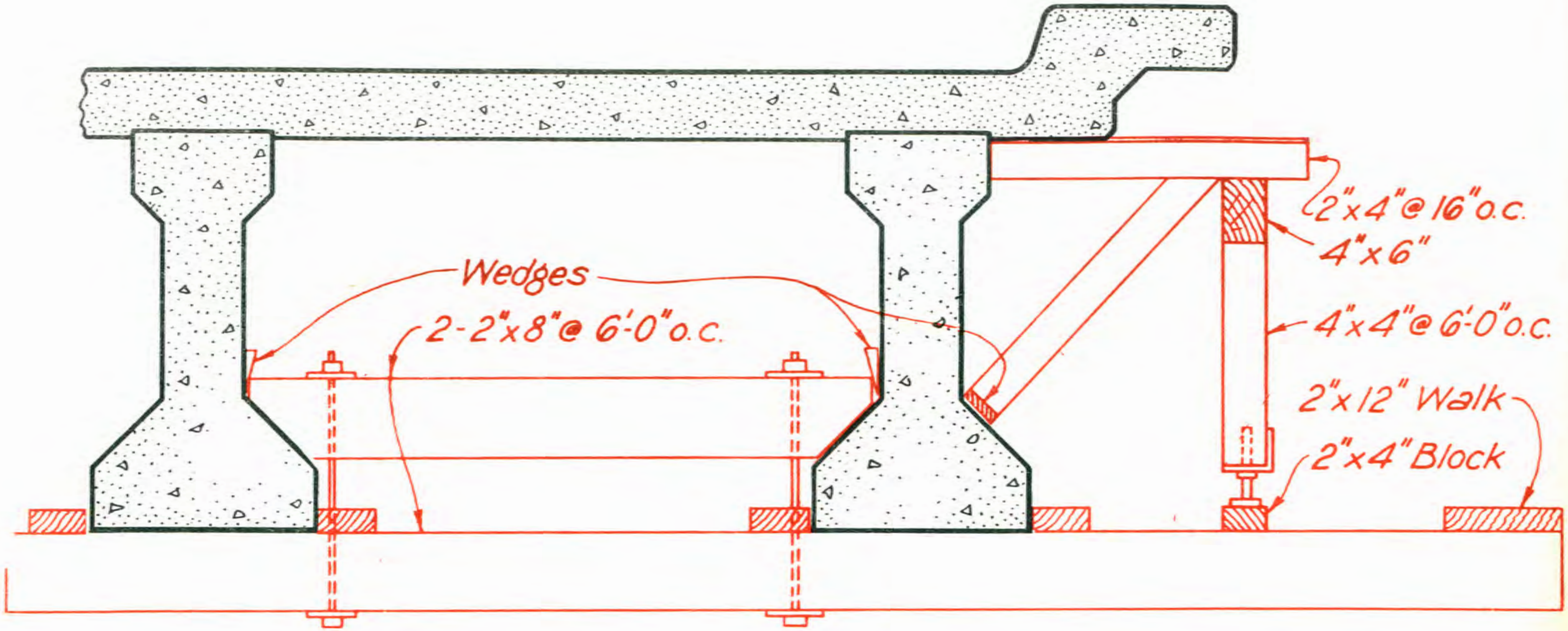
FIG. 33



OVERHANG SUPPORT BRACKET

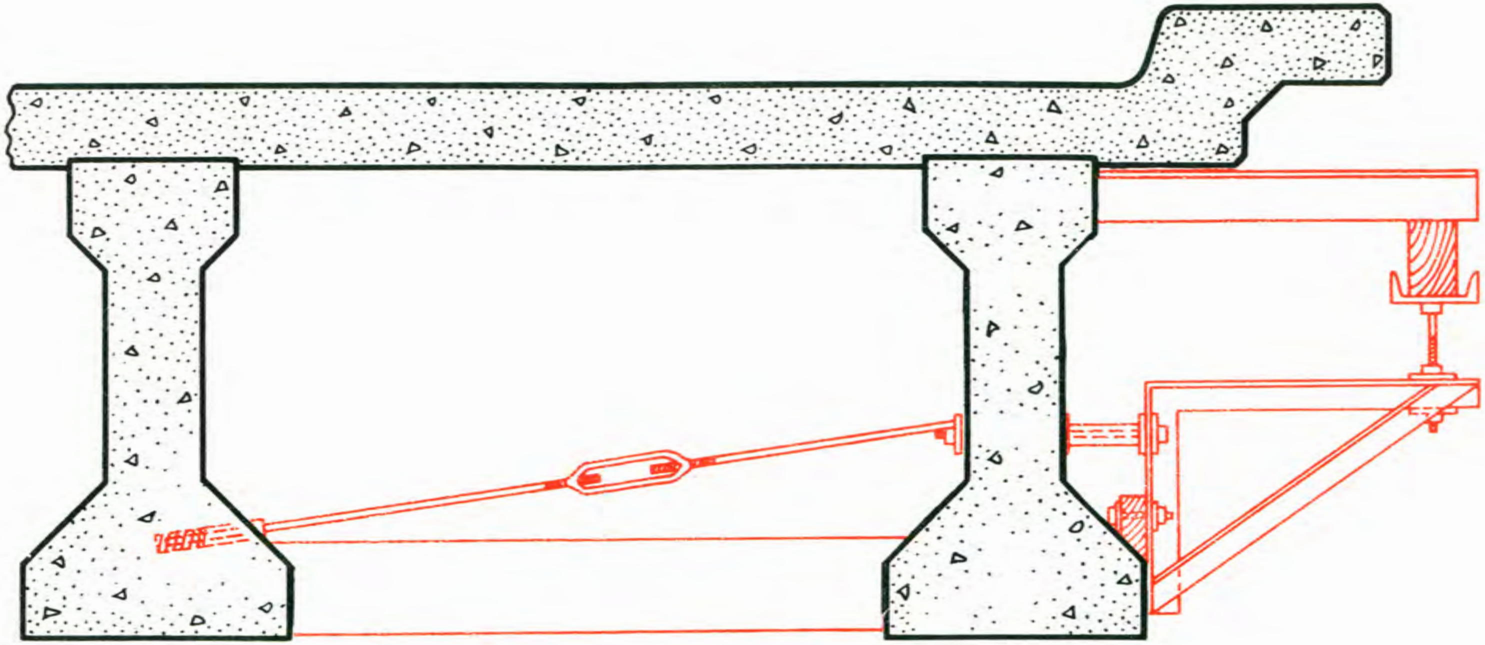
Showing use of Needle Beam supported by bolt in Girder

FIG. 34



(Showing use of Needle Beam supported on Girder Haunches.)

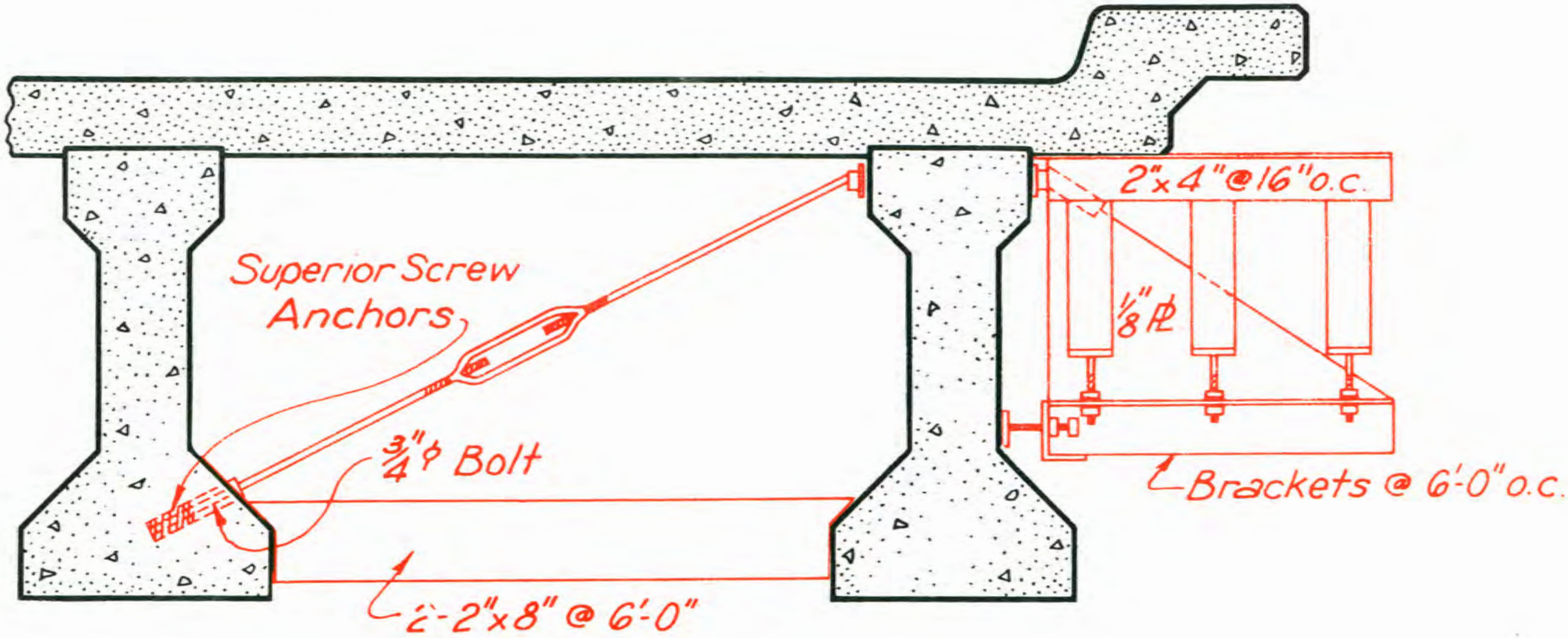
FIG. 35



OVERHANG SUPPORT BRACKET

Showing use of Steel Brackets with the load of the curb being applied to the lower portion of the Beam.

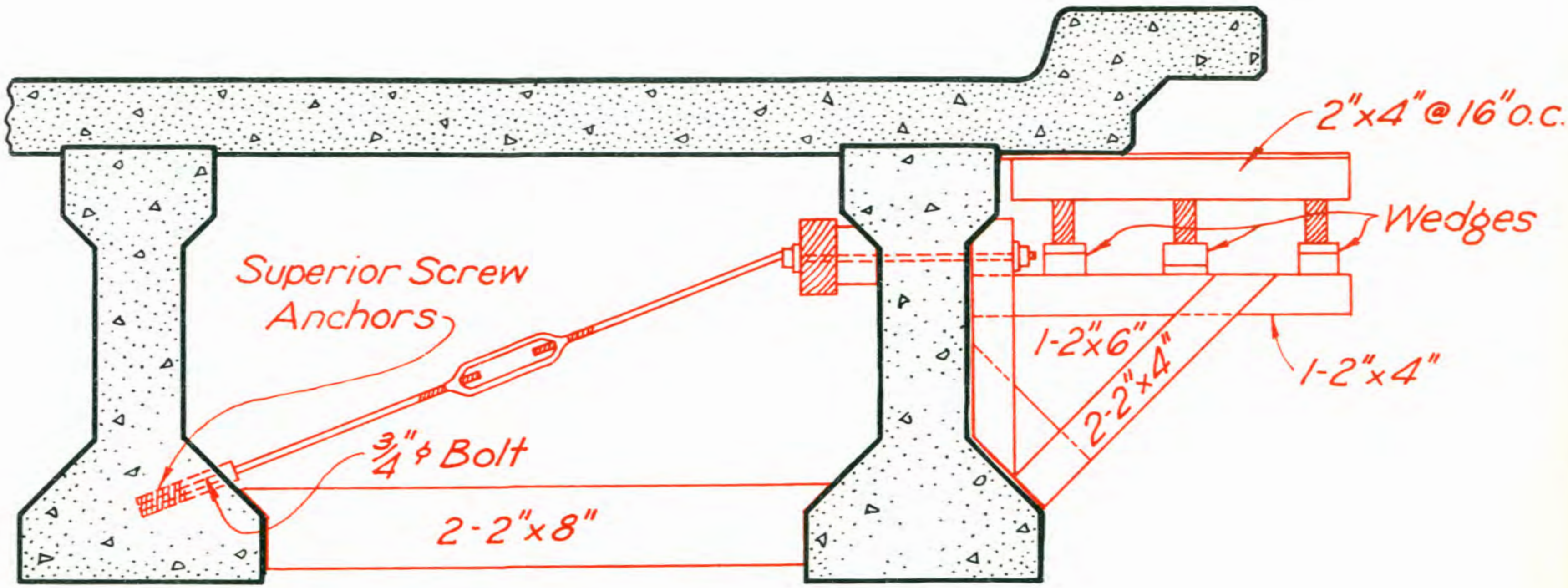
FIG. 36



OVERHANG SUPPORT BRACKET

Showing use of Steel Brackets with the load of the curb being applied to the Top & Bottom flanges of the Beam.

FIG. 37



OVERHANG SUPPORT BRACKET

Showing use of a Timber Bracket with the load of the curb being applied to the Top & Bottom flanges of the Beam.

FIG. 38

Figures 29, 30, 31, 32, and 33 show various types of overhang brackets that may be used that may require additions to the brackets to distribute the load on the stringers. For prestressed concrete structures, needle beams provide a very satisfactory way of supporting slab overhang forms. Normally, all loads are vertical and therefore do not introduce horizontal loads onto the girder. However, this is not always true.

Overhang brackets, adapted from I-beam units, or plate girder units, may be used on prestressed concrete beam structures, if positive measures are incorporated to overcome all horizontal loads on the girders. Compression members must be placed between the bottom flanges of the outside of the girder and the one adjacent to it. Tension members must be used to support the top flange of the outside girder. For your information, Figures 34, 35, 36, 37, and 38 are several types of approved details for forming the slab overhang.

Another method that some contractors use is to tackweld the slab reinforcing steel at points of overhang brackets to the projecting R-bars from the prestressed girder in each bay. This permits the torsion acting on the top flange of the beam and web of the beam to be resisted by the tension of the reinforcing steel in the slab and by the other stringers in the slab. These reinforcing steel bars should be in close proximity to the bracket. It will still be necessary to place compression members between the bottom flanges of the outside girder and the one adjacent where this method is used.

These curb overhang brackets support overhang pans of approximately 5x5, depending upon the amount of the curb overhang. The overhang brackets should be placed on approximately five-foot centers, depending upon the type of stringers supporting the pans. These pans are made of 2x4 joists on sixteen-inch centers, and they are usually capped with three-quarter-inch plywood. The doghouse which forms the overhang of the sidewall is placed on the pan at the correct distance from the centerline of the structure. These doghouses should be made of 2x10 joists on sixteen-inch centers, plus or minus, and should be of the dimensions of the sidewalk overhang. They are then covered with three-quarter-inch plywood. The curb forms should be supported by angle brackets made of $2\frac{1}{2}$"x$2\frac{1}{2}$"x$\frac{1}{4}$" angles on three-foot centers. These angle supports should be adjustable from the bottom of the overhang pan by a vertical adjusting nut in order that the curb forms may be set at the proper height. The back of curblines should be made of 2x8's with a 2x4 cap plate to which is attached a five-eighths inch by six-inch turnbuckle braces on three-foot centers. This is only one approved method of support for curb overhang on prestressed beams and continuous I-beam units. Other methods that are shown on other types of detail brackets may be satisfactory for use.

The final line of the outside edge of the concrete deck should not be established on the overhang forms until the deck form has been graded. The required distance is then measured from the centerline of the slab that is to be graded. The chamfer strips and outside forms are then set to this line and nailed securely. The top of the concrete grade is set on the outside form by measuring the required depth vertically from the overhang deck forms at each grading point. These grading points should be spaced so as to fall directly over the overhang support brackets. In grading the empty overhang forms, the dead load deflection and anticipated amount of form settlement must be added to a theoretical elevation. After this top grade is measured and the chamfer set, a visual inspection should be made to see that the gradeline is smooth and uniform.

2. <u>Pouring and Finishing</u>

After sufficient longitudinal sections have been placed on the slab, the concrete should then be placed in the curb forms. The form should be filled with excess material and the excess struck off with a wooden template, forcing the coarse aggregate below the mortar surface. The use of mortar topping for surfaces under this classification will not be permitted.

After the concrete has been struck off as described above, the surface shall be worked thoroughly with a suitable float. After floating and before the finish has set, all surfaces except sidewalks so finished, shall be striped lightly with a fine brush to remove the surface cement film, leaving a fine grain, smooth but sanded texture. That portion of curbs or parapets which is to be a seat for concrete rail posts, or webs of concrete railing, shall be roughened in an approved manner.

Grading the overhang deck after the concrete has been placed in the curb forms will depend upon the type of bridge deck being constructed. If the slab is a part of the continuous unit, the theoretical elevations have to be adjusted to compensate for a temporary deflection created by an unbalanced load. The height of the header above the grade point should be checked to see that the bolts and forms remain firm. Then the actual theoretical elevation of the header should be taken with an Engineer's level and compared with the theoretical elevation of the header or joint at the same point. The difference is the amount of temporary deflection in the slab. This same difference must be added to or subtracted from the theoretical elevation of the overhang at the same station. This will be at construction joints or armor joints. This difference is then transitioned out within the slab being poured at .005 of a foot for each overhang bracket grading point until all the difference has been eliminated.

In grading the overhang of a simple span, there is no temporary deflection, since each end of the slab is supported by a pier or abutment and all grades will be set to the theoretical elevation. To grade the top of the overhang after the concrete has been placed, a level shot should be taken at each grading station and the overhang raised or lowered to the desired elevation by turning the adjusting bolts in the overhang brackets. It is good practice to grade the overhang forms at least two times, because when a point is first adjusted, it will change the previously graded points, slightly.

To check the line of the outside form after the concrete has been placed, the distance from the centerline of the slab to the edge is checked at each end of the slab being poured. A 3/4" block of wood can then be nailed to the inside base of the form at each end and a stringline stretched taut along the slab. The outside curb form line can then be checked at each form adjustment point with another 3/4" block.

In order to facilitate the slab finishing, forms for inside curb faces on the roadway base may be removed in not less than three hours if the concrete has set sufficiently to permit form removal without damage to the curb. After the forms have been removed and all repair work and straight edging and pointing of the curb has been done, the first rubbing on the curbs can be performed.

The top grade of the curb may be checked with a 3/4" spacer block placed at each header and drawn taut and by placing a 3/4" block along the string at various distances from the back of the curb, the top of the curb can be brought to the correct elevation. This applies to the front face of the curb, also.

If these methods are followed and the Inspector is on the job to see that these items are carried out, there should be no reason for the curb to have bulges or dips in it.