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A study of the economic design of short span girder type concrete-steel highway bridges

Enoch Ray Needles

A STUDY OF THE ECONOMIC DESIGN OF SHORT SPAN GIRDER TYPE CONCRETE-STEEL HIGHWAY BRIDGES.

By

ENOCH RAY NEEDLES.

A

THESIS

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A Study of the Economic Design of Short Span Girder Type Concrete-Steel Highway Bridges.

The general principles underlying the design of concrete-steel structures are quite well known. Concrete itself is a structural material which is sightly, permanent, very strong in compression, thoroughly reliable when made honestly, almost fool-proof when once allowed to "set" properly, adaptable to an almost unlimited number of uses, practically fire-proof as well as water-proof, and in addition its cost is always very reasonable. The great objection to concrete is its lack of tensile strength, and likewise its lack of elasticity and toughness.

Thus it is a fortunate circumstance that ~~a metal~~ which is one of the least expensive of metals, and which possesses to a marked degree those qualities which plain concrete lacks, also has a coefficient of expansion which is almost identical with that of concrete. Thus steel may be imbedded in concrete in the proper place, manner, and amount, and the resulting combination called "concrete-steel" possesses the good qualities of both of the above mentioned materials, the steel supplying the tensile strength, while the concrete supplies the compressive strength. No fear need be felt concerning the breaking of the bond between the concrete and the steel due to temperature changes, and in addition, the life of the steel is made practically everlasting, as numerous and varied cases have proven that the concrete covering stops all oxidation or other decomposition of the steel, and gives it permanent and complete protection. From these facts the many points in favor of concrete-steel construction are very evident.

The saying that a chain is "no stronger than its weakest link" is especially applicable to concrete-steel. The duty of the designer is to proportion and place the concrete and the steel so that each will be stressed properly and in proportion. For example, in case of failure of a concrete-steel beam, the failure should ideally be due to both the crushing of the concrete in the upper part of the beam, and the simultaneous yielding of the steel in the lower part of the beam. It may be well to note here that while the ultimate strength of the concrete in such a beam is the ultimate compressive strength of the concrete, the ultimate strength of the steel in such a beam is the yield point of the steel in tension. In properly proportioning and placing the materials in a concrete-steel structure, the designer is, as in all other engineering work, "making a dollar do the most good". It is a notable fact that under present conditions, a proper proportionment of materials in a concrete-steel structure for the stresses involved, also results in approximately the most economic combination of the two materials.

Just at this time the people in all parts of the country are awaking more than ever to the fact that good roads are necessary as well as pleasurable. The desire for an economical, satisfactory, and permanent roadbed does not greatly exceed the desire for economical, sightly, and permanent highway bridges. Wooden bridges are cheap, but are unsightly, subject to rapid decay, and soon become unsafe. Steel bridges are strong and fairly cheap, but they are unsightly also, and soon begin to deteriorate, the average life being not much more than twenty years or so. The upkeep on both of these types is considerable. The concrete or concrete-steel bridge costs but little more than the steel bridge, its life is practically without end, it is always a source of pride and pleasure, the upkeep amounts to nothing, and most of the money spent for the labor and materials necessary remains in the neighborhood in which the bridge is built.

In selecting this subject for a thesis, it was borne in mind that not only should room be given for plenty of study, research, and design, but also that the work should be appropriate both to the student and present conditions. Therefore a "Study of the Economic Design of Short Span Girder Type Concrete-Steel Highway Bridges" was undertaken. The plain girder type was adopted as being more adapted to the student's preparation and ability, the arch being much more difficult of calculation, and much less satisfactorily interpreted. The combined arch-girder would be better adapted to some of the designs submitted than the plain girder, but much experience is desirable to insure the wise and satisfactory design of such types. The short spans only were studied inasmuch as the plain girder spans are limited by economy and practicability. All study of abutments was omitted, as local conditions would decide such designs.

In order to give a fairly good comparison of costs, prices for steel and concrete were adopted, which should give a just basis for comparison of the different types. The first three types would require no experienced formsetters or laborers, the designs being very simple. The other types would require more careful work and experienced labor. Beyond doubt all the work could be done quite well by workmen not especially expert, but careful work would be necessary, and experienced labor would very likely prove more satisfactory, expeditious, and economical. Hence, the different costs given the concrete per cubic yard. A standard width of roadway was necessarily adopted to provide the desired comparisons.

Turneaure and Maurer's "Principles of Reinforced Concrete Construction" was the reference book for this study. The approximate formulae found therein were adopted, as they shorten the computations and give results in all cases abundantly safe. The allowable stresses adopted for the steel and concrete are those very commonly used in good practice, and the loads assumed are rather more extreme than the ordinary. Thus the resulting designs are undoubtedly on the safe side. The concrete used in the construction of such bridges should be 1:2:4 concrete of properly selected materials, and the steel used should have a yield point not lower than 40,000 pounds per square inch.

In this study, all slabs were studied as being made up of independent beams, each 12 inches wide-the resulting surplus strength of these slabs is obvious. The floor girders and side girders were all treated as T-beams according to the approximate formulae of Turneaure and Maurer.

In Design No. I the reinforcing is run parallel with the span, which is obviously the most economical, the span being 10 feet and the width 16 feet.

In Design No. II the same plan is followed for the twenty foot span, with the resulting increased thickness of slab and amount of steel used. In these two designs the side girders act merely as guard rails.

In Design No. III the steel is run across the bridge, the side girders carrying the load. Thus the floor thickness is cut down, while the strength of the side girders is utilized. The saving over Design No. II is pronounced.

In Design No. IV, T-beam floor girders are used running parallel with the span, each T-beam carrying the load imposed upon it independent of the other T-beams. The floor slab is thus made thinner, the total dead load cut down, the strength of the concrete in compression is utilized more fully, the steel needed is cut down, and the result is a cheaper and lighter bridge. The increased cost in this case due to more complicated formsetting, etc., is allowed for in the estimate.

In Design No. V the T-beam floor girders run across the bridge, the side girders carrying the total load. For the 20 foot span, Designs IV and V are practically the same in utilization of strengths of materials, but Design IV requires some less material.

In Design No. VI we find No. IV applied to a thirty foot span with the resulting increased thicknesses of concrete and amounts of steel.

Design No. VII is No. V applied to a thirty foot span. The comparison of No. VI and No. VII shows the effect of increase of span on the two types. In No. VI the floor slab and T-beam girders must increase with any increase in span length, while for No. VII the floor system is a constant quantity for all span lengths, only the side girders alone increasing. Thus No. VII proves to be the proper type where the span considerably exceeds the width.

Design No. VIII is type No. V applied to a forty foot span, with the increased size in side girders. Thus we see that the type of bridge No. VIII is limited only by the size which the side girders must attain. No doubt this type of bridge could well be used up to seventy or seventy-five foot spans, but for such spans undoubtedly the arch or arch-girder would prove a better choice. However, the head-room necessary, and the roadway grades desired, as well as many other conditions more or less local, would play a great part in the design of bridge adopted.

Very respectfully submitted,

Enoch R. Needles.

May, 1914.

CONCRETE-STEEL

HIGHWAY BRIDGE DESIGNS.

GIRDER TYPE.

Width of Roadway — 16 Feet.

Span Lengths — 10 to 40 Feet.

Live Load { 125 lbs. per sq. ft. or 20 tons on 6' x 12'.

Weight of Concrete — 150 lbs. per cu. ft.

Weight of Pavement — 75 lbs. per sq. ft.

Allowed Stresses { $f_s = 16{,}000$ #/□" ; $f_c = 500$ #/□" } $n = 15$.

Note — In the Webs of All T-Beam Floor Girders, Stirrups are to be used, of $\frac{1}{2}$" □ Bars, 1' O.C. —

Stirrups not shown in Drawings.

May-1914.

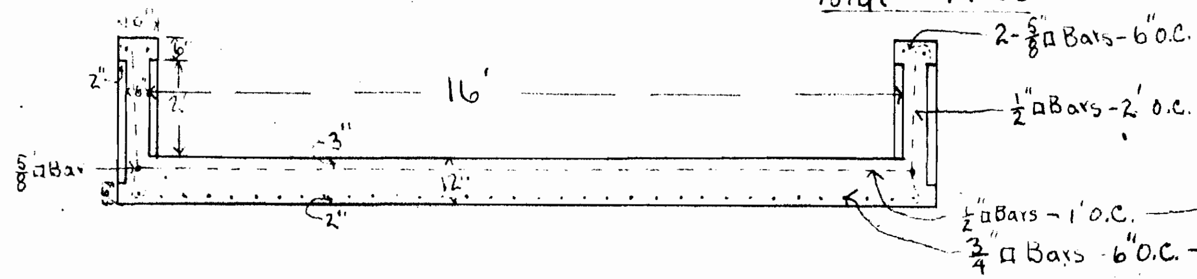
E.R. Needles - M.S.M

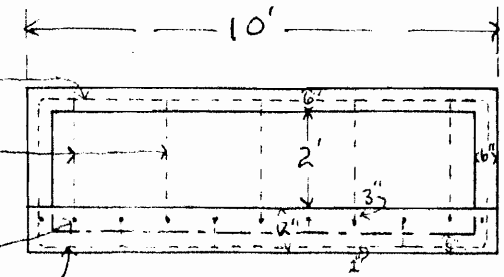
Design No. I.

Width-16'. Span 10'.

Estimate.

Concrete – 7.2 cu. yds. @ $5 – $36.00
Steel – 666# @ 2¢ – $13.30
Total – $49.30



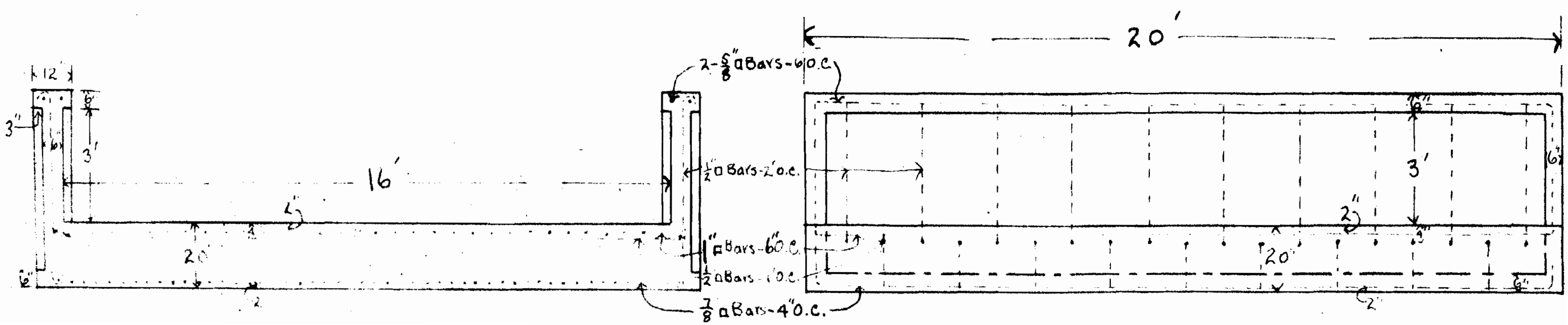


Design No. II.

Width-16'. Span-20'.

Estimate.

Concrete – 24 cu. yds. @ $5 – $120
Steel – 5808# @ 2¢ – 116.15
Total – $236.15

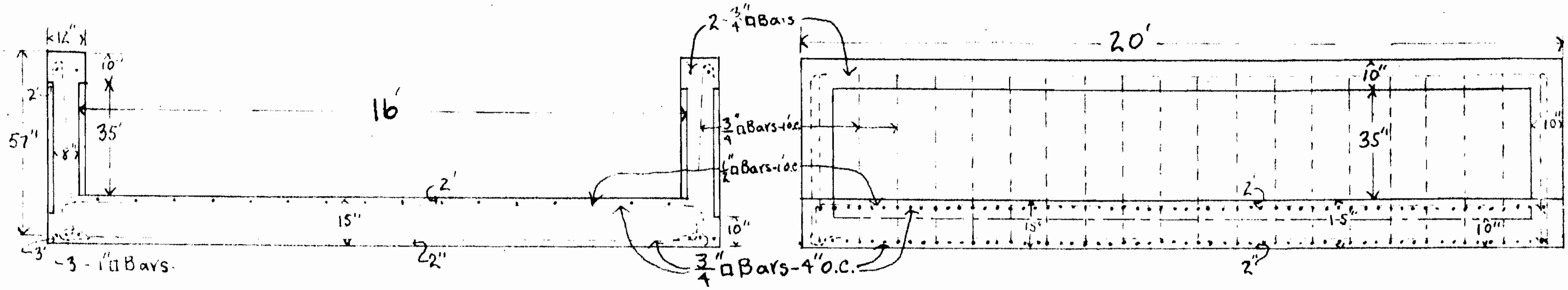


Design No. III.

Width 16'. Span 20'.

Estimate.

Concrete - 20.8 cu. yds. @ $5 — $104.00
Steel — 4981# @ 2¢ — 99.60
Total - $203.60

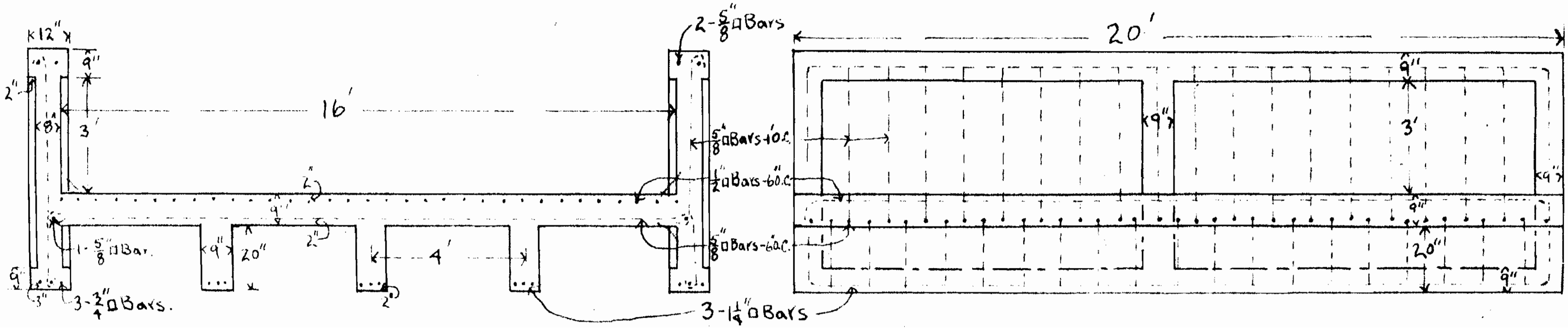


Design No. IV.

Width - 16'. Span - 20'.

Estimate.

Concrete – 17.1 cu. yds. @ $7 – $119.90
Steel - 3312# @ 2¢ – 66.25
Total - $186.15



Design No. V.

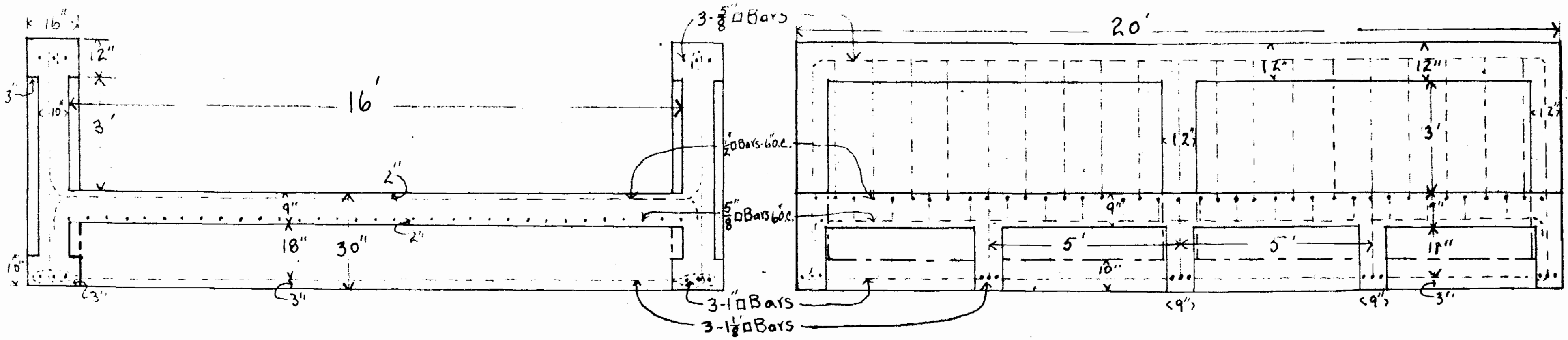
Width-16'. Span-20'.

Estimate.

Concrete - 22.2 cu. yds. @ $7 - $155.40

Steel - 3306# @ 2¢ - 66.10

Total - $221.50



Design No. VI.

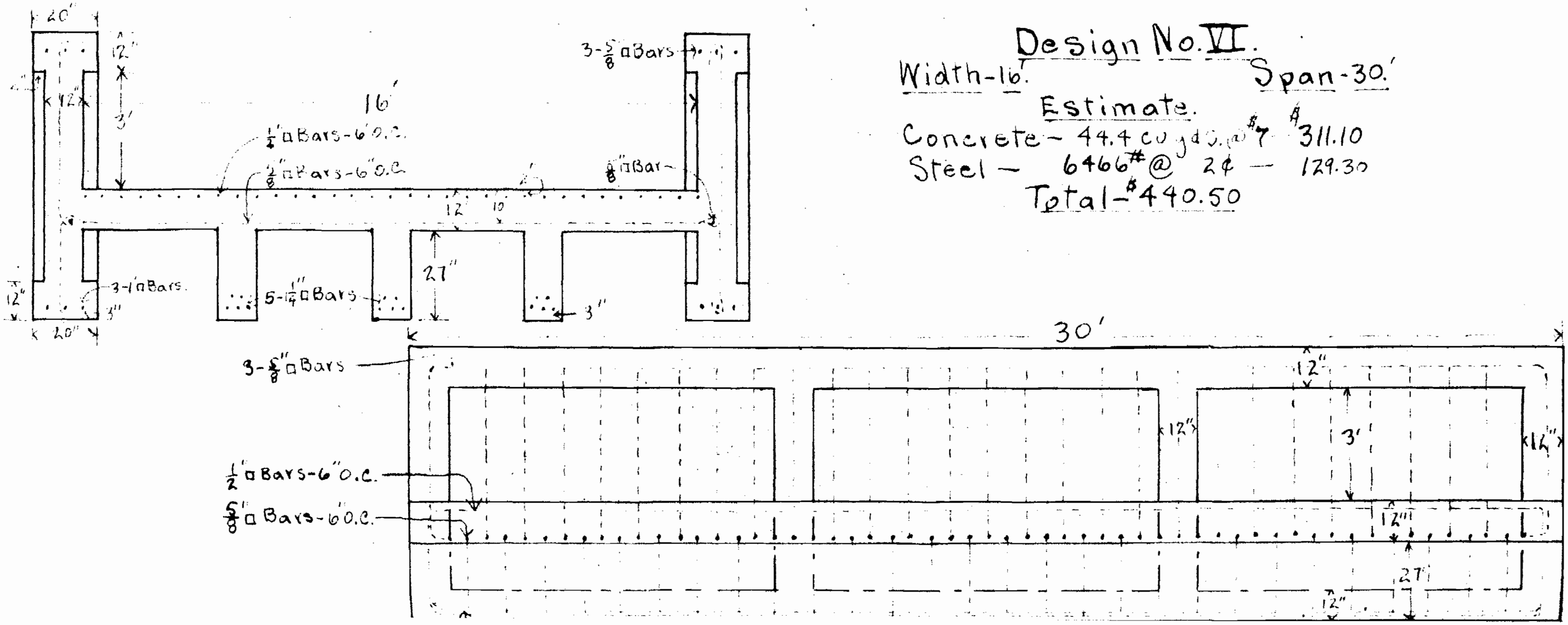
Width-16'. Span-30.'

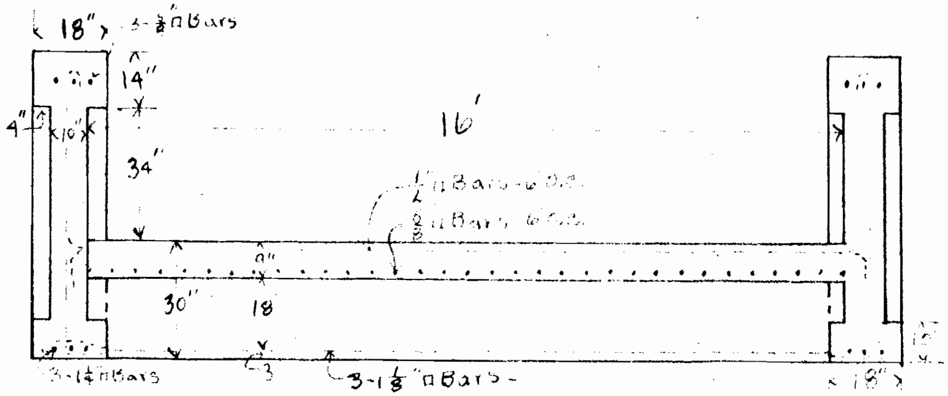
Estimate.

Concrete - 44.4 cu. yds. @ $7 - $311.10

Steel - 6466# @ 2¢ - 129.30

Total - $440.50





Design No. VII.

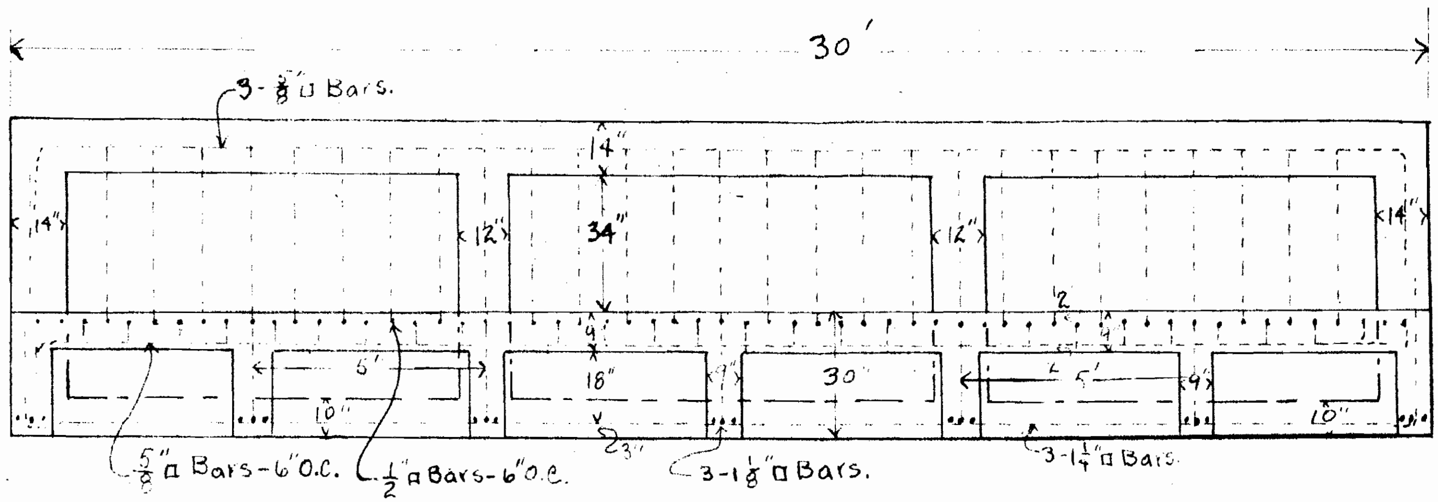
Width-16' Span-30'

Estimate.

Concrete- 33.7 cu.yds. @ \$7- \$235.90

Steel- 6450# @ 2¢ - 129.00

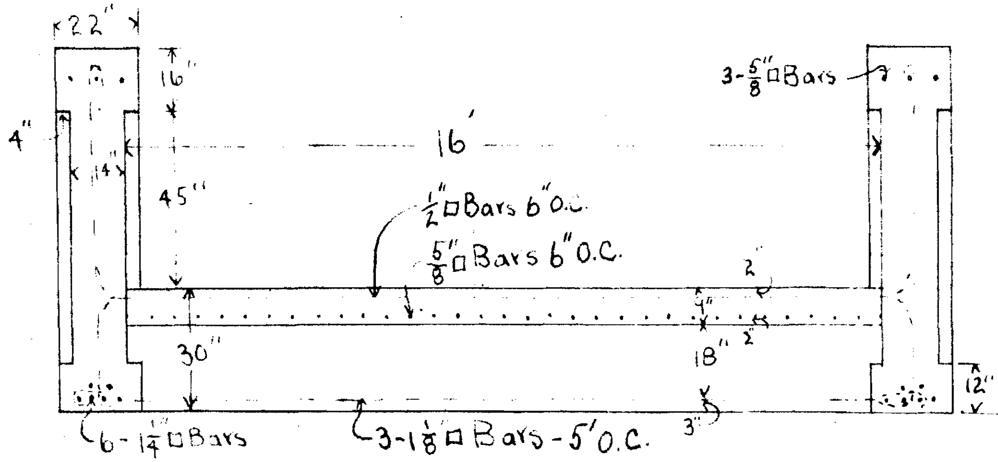
Total- \$364.90



Design No. VIII.

Width 16'

Span 40'.



Estimate.

Concrete – 55.65 cu.yds. @ $7 – $389.55

Steel – 9348# @ 2¢ – $186.95

Total – – $576.50