THE THEORY OF ESTIMATING

Thesis for Degree of C. E.

FENT EDWIN N. THATCHER

1913

# THE THEORY OF ESTIMATING.

Its relations to the shops, cost of production and the conditions of supply and demand.

Thesis by

Fent Edwin N. Thatcher.

For the degree of Civil Engineer.

1913.

THESIS

Preface.

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The author of this thesis is indebted to the following people for the privilege of being able to write for the Civil Engineer's degree. To Philip P. Schnorbach of Muskegon, Mich., for his interest taken in me after leaving high school by giving me a job as timekeeper on government pier construction at Ludington. To Tom F. Rogers of Ravenna, Mich. ( M.A.C. 1874) for advising me to take the Engineering course at the Michigan Agricultural College. To my parents for making it possible for me to attend college. To the Engineering department of the M.A.C. for the theoretical knowledge I received and for advice I have received which I hope has been applied successfully. To C, Ulrich Malin of the Shaw Electric Crane Company of Muskegon, Mich., for my training in practical estimating. To H. J. Cox of the Mississippi Central R. R., and Chas T. Bird of the American Steel Foundries. Alliance, Ohio, for my training in practical construction. To Fred W. Brown, Supt., Beach Mfg. Co., Charlotte, Mich., for making many of my designs practical as regards shop work and erection. To Chester A. Brewer for my training in baseball, many points of which have served me allegorically since leaving school. I have this to say of myself- that it is " up to me" to make good in order to show my appreciation.

Fent Edwin N. Thatcher.

Estimating is that process which teaches us to arrive at a reasonable figure on any proposed object, by basing that figure upon known figures for objects of a like nature.

By reasonable figure, I mean a figure such that its nearness to the final figure will be within certain limits which are determined by the other factors in the problem. This limit is fixed to a certain degree by the amount of data one has of similar problems which have previously been completed.

To begin with, nothing in practice can be measured exactly, but it can be made close enough for the purpose at hand. We measure structural steel to a 32nd of an inch, we shear it to within a quarter of an inch, we saw to a closer limit, we grind it to a fifth of a thousandth of an inch; but the smaller the limit the higher the cost. When we buy steel we work to a specification which makes an allowance in weight for the inaccuracy of the mill.

And it is this part of estimating (which comes under the head of structural steel) that this thesis will tend to show. The fundamental thot in estimating comes from the fact that man must eat in order to live and that in order to live each man is dependent upon every other man. From this fact, every estimate must be figured finally in financial terms. The two main parties interested in the estimate are the people who have to eat and the people they are dependent upon. Suppose a bridge is destroyed between a town and a farming district. This raises prices in the town and the difference in price creates a desire for a new bridge. The consumers estimate the value of the bridge.

The people upon whom they depend estimate what such a bridge will cost and then fix the price which is between the actual value of the bridge and the cost of same and is as near the actual value as is possible while estimating the price to be lower than that fixed by their competitors for they in turn must eat. This is the theoretical condition affecting the sale. Hence the greater the competition the lower the price, on the bid. This is the SALESMAN'S estimate. He knows the cost and he estimates the rest.

The salesman however gets his cost from

the Sales Department. They get the cost from the following data-

(A) Weight of steel bought at mill prices multiplied by cost per pound.

(B) Weight of steel bought at warehouse price multiplied by cost per pound.

(C) Cost of production as estimated from previous work.

(D) Cost of loading.

(E) Overhead percentage, to take care of selling, engineering, office and factory superintendence, cost of upkeep of shops, interest on investment.

(F) Freight and hauling.

(G) Erection.

An estimate sheet should show these various parts of the problem.

Every company keeps a record of steel on hand, steel requisitioned for various jobs and steel on order. From this record and the rolling schedules of the mills they are able to figure what they must buy short from the warehouses.

From this they estimate the proportion of steel at mill prices f.o.b. cars at shops and that from the warehouses which will go into the job. They get the estimated weights from the Engineering Department, together with the amount of work to be done on each piece. Their costs for the work are figured from the records of the cost department, which also furnishes them basis for adding an overhead expense percentage. To this is added the freight and hauling and cost of erection , which is determined by the engineering and cost departments.

The cost department keeps a record of each job as it goes through the shops in such a manner that the engineering department is able to make designs of saving value which at the same time do not impair the strength of the member. The cost department also keeps a record of all expenses termed overhead which is spread upon the jobs according to their proportion of the total jobs. This overhead of course is an estimated quantity for future work and in order to make a higher profit a company tries "to cut down the overhead".

Upon the Engineering department falls the greatest proportion of the efficiency work in a structural shops. The Engineering department furnishes the "show" drawings, which gives the size of the members, the stresses in each piece, the specification worked to, and with the drawing, it also furnishes the estimated weights of the steel. The salesman's job then reduces itself, as far as costs are concerned, to a case of simple multiplication. In other words the salesman multiplies the weight by the cost per pound and adds some percentage furnished him by the selling department.

These show drawings are always based on the most economical use of the steel as regards cost. For instance, take a 10"-40# beam for a span of 12 feetwhich carries a safe load of 28210# and, without doing any harm to the structure, it would be advisable to change to a 12"-31 1/2# beam, which is good for

31,970#. The 10-40# cannot be gotton from the mills in less time than 2 months, while the 12"- 31 1/2 I is in stock. This would be a saving of 8 1/2# or possibly 20 cents per ft., while the time is worth much more than this. Or take a 4 1/2 X 3 X 3/8, weight 9.1# which bought at warehouse price might equal 9.1 X 2.1¢ = 19.11¢ per ft., while a 5 X 3 X3/8 angle, weight 9.8#, would be in stock and is worth 9.8# X 1.2¢ = 11.76¢ per ft. It would pay to use the heavier angle, which at the same time could be sold for more money: taking the two cases in the same problem and we would have a balanced job, but would be able to deliver the same in less time. As delivery is an important factor in any case, it is up to the Engineering department to watch this phase of the work in the design.

Another thing affecting the design of the job is the facilities a shop has for doing a certain class of work. The Engineers must know the shop equipment and be able to determine from the records and by judgment the best possible way to do work.

The whole essence of an estimate may be summed up in the following words,

To get a design that will sell.

To get a design that is not costly.

To get a design that can be made in the shops efficiently.

To get a design that can be shipped.

To get a design that can be erected at a low cost.

To get a design of sufficient strength and beauty to sell another job in the same locality.

To do these things makes a business profitable, and this reflects upon the Engineer, who, in turn, is able to command more money for his work.

Again to have the interest of all parties in mind, and to work honestly along these lines, makes the estimator successful.

No concern can be profitable unless the shops work to an advantage. An Engineer plans his work for the benefit of the shops and the shops must try to do their part. If the Engineer has erred in judgment the shop foreman should make this plain to the Engineer. In so doing, he lowers the cost of the next design and keeps the shops busy on a class of work which is profitable. This fixes the pay of the men in the shops.

One purpose of this thesis is to show that an estimator in order to do good work must value all the actions and reactions which may be caused by the problem he has in hand. Knowing these general relations, he is able to go ahead with any specific estimate and do justice to it.

PRACTICAL ESTIMATING.

Below is shown the cost of steel and the cost of fabricating the same. The cost of steel is always given at some price which is known as the base. Each company has its costs for doing work which are fixed for an indefinite period and is the constant. The base is the variable so that the net selling price is the base plus fabrication multiplied by the number of pounds.

The way of figuring costs is as near as we can get to the actual cost under the present system. As long as all shops use the same formula each will have the same chance in competition. The error in figuring this way is the shops can punch one one=sized hole in a 100# of steel at less than they can punch ten one sized holes, but these things average up.

## STEEL - COST AND FABRICATING.
## FOR APRIL 1912.

| | | Per 100# | |
|---|---|---|---|
| | | Mills | Warehouse |
| Bars and bands | Base Charlotte---- | $ 1.10 --- | $ 1.50 |
| Angles, channels, tees | | | |
| under 3" | Base fob Charlotte--- | 1.10---- | 1.50 |
| Plates and structurals | | | |
| Base fob | Charlotte--- | 1.20 --- | 1.60 |

### SHOPWORK

Punched channels and beams---

One sized hole in either flange---------------- .15

One sized hole web and flange or both---------- .25

Each additional sized hole -------------------- .15

for buildings only.

Punched angles----------

Not less than 1 ft. o.c.----- .35

3 X 3. 4 X 4. 5 X 3 1/2-----

Riveted back to back------------------------ $ 1.00

Punching 6 X 6. 6 X 4. 5 X 5.--- .20

Riveted back to back---------- .60

BEAMS AND CHANNELS-

12 & 15"----------------- .50

18, 20 & 24------------- .40

7, 8, 9 & 10------------ .75

3, 4, 5 & 6------------- $ 1.00

Countersinking add----- .10

Coping beams and channels with

conn. angles------------ .35 over 12'

7, 8, 9, over 8'------- .50

3, 4, 5, 6 over 5'----- 1.00

above include punching.

Add for C I separators and connection angles 1.55

Add for putting beams together

with separators.---------- .10

ESTIMATING THE WEIGHT.

Plain beams, angles, etc. are gotten by multiplying the total number of lineal feet by the weight per foot and adding a small percent, say 3%, to take care of the scrap. This percentage is forgotten by some estimators, but it should be added in for the reason that the shops have to buy more than they sell and the difference is the scrap percentage.

SCRAP PERCENTAGE.

| | tons | |
|---|---|---|
| Steel on hand Jan.1,1912 | 500 | |
| Amt, of steel recd.-6 mon. | 200 | |
| Amt. steel used- shipping wt. | | 496 |
| Amt. steel on hand July 1,1912 | | 183 |
| Amt. scrap | | 21 |
| | 700 | 700 |

Scrap divided by number tons actually sold equals % or 21 ÷ 496 = 4.24% Hence in checking up for 6 months of estimating we would be short 1.24%

For the next period we would add 5% and at the end of that time would check against the records and correct again.

To figure beams punched and riveted together or connected by means of separators, and beams with connection angles on. Figure plain beams, then connection angles, separators, etc. As the beams in a building are nearly always around a certain length for a certain heigth of beam we can from a number of cases figure a percentage which will practically take care of the connections, etc. This however would be used only in case of a rush job.

For Trusses.

We are always able to get the length of the members, but cannot take time to calculate rivet heads and size of gussets. From actual designs, it is found that in trusses of any certain type the weight of rivets and gussets bear a ratio to the main members. In Fan or Fink type trusses of ordinary span the ratio is 5% for rivets, 16% for gussets, and say 3% for scrap or in other words 24% is added to the main members.

Another way is to plot curves of trusses

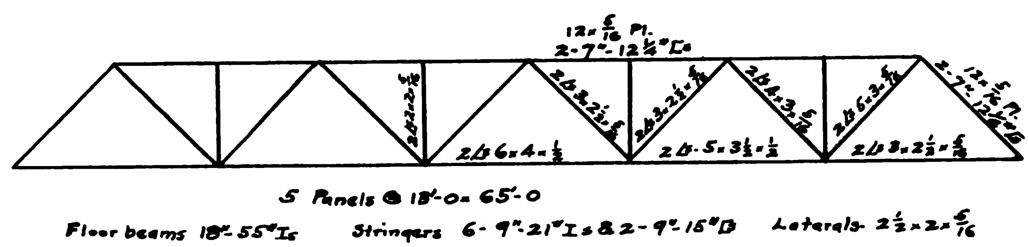
of any type and use this curve for estimating purposes.

Columns in buildings may be worked out in the same way although a short column is heavier in proportion at the ends than a long column.

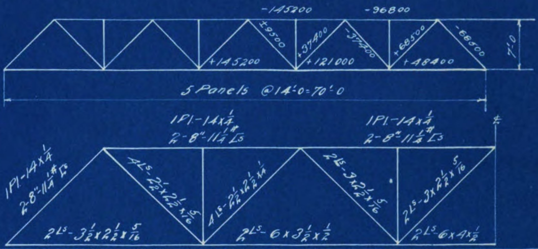
Problem--

A 65' span, 16' roadway, concrete floor, 5 panel low, riveted Warren truss. Live load; uniform 100# per sq. ft. of roading, concentrated, 15 tons roller, 10 tons on rear axle and 5 tons on front axle. Wisconsin State Highway Bridge Specification.

From the problem we get the following stress diagram and the resulting members are shown.




Wisc. State Highway Spec.




# Shipping List
## Name of Structure—70'x16' Bridge
## Place—Branch, Mason Co. Mich.

| No. Pcs. | NAME | MK | Shipment No. | Shipment Date | Assem MK | No. Pcs. | SECTION | Ft. | Ins | Wght. per ft. | WEIGHT | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Trusses | | | | | 4 | 14x$\frac{1}{4}$ Pls. | 10 | 4$\frac{13}{16}$ | | 495 | End Posts |
| | 3 Parts each | | | | | 16 | 4x$\frac{1}{4}$ Pls. | 1 | 1$\frac{3}{4}$ | | 62 | |
| | | | | | | 8 | 8" [s | 10 | 4$\frac{13}{16}$ | 11$\frac{1}{4}$ 80% | 936 | |
| | | | | | | 8 | 12x$\frac{1}{4}$ Pls. | 2 | 6 | | 163 | |
| | | | | | | 8 | 5x3$\frac{1}{2}$x$\frac{3}{8}$ Ls | 1 | 0 | | 83 | |
| | | | | | | 8 | 3x2$\frac{1}{2}$x$\frac{5}{16}$ Ls | 1 | 0 | | 45 | |
| | | | | | | 4 | Shoes 14x$\frac{3}{8}$ | 1 | 6 | 95% | 101 | Cut to temp. |
| | | | | | | 4 | Bent Pl. 8x$\frac{1}{4}$ | 0 | 7$\frac{5}{8}$ | | 17 | |
| | | | | | | 920 | $\frac{3}{4}$ Riv. Hds. | | | | 148 | |
| | | | | | | 648 | $\frac{5}{8}$ Riv. Hds. | | | | 84 | |
| | | | | | | | | | | | | |
| | | | | | | 4 | 14x$\frac{1}{4}$ Pls. | 14 | 1$\frac{3}{4}$ | | 673 | Top Chord |
| | | | | | | 2 | 14x$\frac{1}{4}$ Pls. | 28 | 0$\frac{1}{4}$ | | 667 | |
| | | | | | | 4 | 14x$\frac{1}{4}$ Pls. | 1 | 3$\frac{1}{4}$ | | 60 | |
| | | | | | | 8 | 8" [s | 14 | 1$\frac{3}{4}$ | 11$\frac{1}{4}$ | 1272 | |
| | | | | | | 4 | 8" [s | 28 | 0$\frac{1}{4}$ | 11$\frac{1}{4}$ | 1281 | |
| | | | | | | 48 | 4x$\frac{1}{4}$ Pls. | 1 | 1$\frac{3}{4}$ | | 186 | |
| | | | | | | 4 | Caps 14x$\frac{1}{4}$ | 0 | 6$\frac{1}{4}$ | | 25 | |

# Shipping List
## Name of Structure—70'x16' Bridge
## Place—Branch, Mason Co. Mich.

| No. Pcs | NAME | MK | Shipment No | Shipment Date | Assem MK | No. Pcs | SECTION | Ft | Ins | Wght per ft | WEIGHT | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 8 | Caps $18 \times \frac{1}{4}$ | 3 | 0 | | 367 | Cut to temp. |
| | | | | | | 4 | $18\frac{1}{2} \times \frac{1}{4}$ | 1 | $0\frac{3}{4}$ | | 67 | Cut to temp. |
| | | | | | | 8 | $19\frac{1}{4} \times \frac{1}{4}$ | 2 | 2 | 75% | 212 | Cut to temp. |
| | | | | | | 16 | $3 \times \frac{1}{4}$ Pls. | 0 | $10\frac{1}{4}$ | | 35 | |
| | | | | | | 1056 | $\frac{3}{4}$ Riv. Hds. | | | | 170 | |
| | | | | | | 2064 | $\frac{5}{8}$ Riv. Hds. | | | | 205 | |
| | | | | | | | | | | | | |
| | | | | | | 16 | $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ | 6 | 2 | | 403 | Verticals |
| | | | | | | 16 | $3 \times 3 \times \frac{3}{8}$ | 0 | $4\frac{3}{4}$ | | 45 | |
| | | | | | | 192 | $\frac{3}{4}$ Riv. Hds. | | | | 31 | |
| | | | | | | 16 | $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ | 8 | $8\frac{3}{4}$ | | 698 | Diagonals |
| | | | | | | 16 | $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ | 8 | $5\frac{1}{2}$ | | 554 | |
| | | | | | | 8 | $3 \times 2\frac{1}{2} \times \frac{5}{16}$ | 8 | $8\frac{3}{4}$ | | 390 | |
| | | | | | | 8 | $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ | 0 | $5\frac{7}{8}$ | | 19 | |
| | | | | | | 8 | $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ | 0 | $8\frac{1}{8}$ | | 27 | |
| | | | | | | 8 | $3 \times 2\frac{1}{2} \times \frac{5}{16}$ | 8 | 8 | | 387 | |
| | | | | | | 44 | $14 \times \frac{1}{4}$ Pls. | 0 | $4\frac{3}{4}$ | | 194 | |
| | | | | | | 1056 | $\frac{3}{4}$ Riv. Hds. | | | | 170 | |
| | | | | | | | | | | | | |
| | | | | | | 8 | $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ | 13 | 4 | | 650 | Lower Chords |
| | | | | | | 8 | $6 \times 3\frac{1}{2} \times \frac{1}{2}$ | 13 | $11\frac{1}{2}$ | | 1707 | |
| | | | | | | 4 | $6 \times 4 \times \frac{1}{2}$ | 13 | $11\frac{1}{2}$ | | 904 | |
| | | | | | | 8 | $3 \times \frac{1}{2}$ | 2 | $1\frac{3}{4}$ | | 87 | |
| | | | | | | 8 | $2\frac{1}{4} \times \frac{1}{4}$ | 1 | $0\frac{1}{2}$ | | 16 | |
| | | | | | | 8 | $3\frac{1}{2} \times \frac{5}{8}$ | 2 | 4 | | 138 | |
| | | | | | | 16 | $14 \times \frac{1}{4}$ Pls. | 0 | $4\frac{3}{4}$ | | 74 | |
| | | | | | | 16 | $16 \times \frac{1}{4}$ Pls. | 0 | $4\frac{3}{4}$ | | 85 | |
| | | | | | | 8 | $30 \times \frac{1}{4}$ Pls. | 2 | $10\frac{1}{2}$ | 65% | 381 | Cut to temp. |
| | | | | | | 8 | $30 \times \frac{1}{4}$ Pls. | 2 | $8\frac{1}{2}$ | 75% | 413 | |
| | | | | | | 1136 | $\frac{3}{4}$ Riv. Hds. | | | | 183 | |

# Shipping List
## Name of Structure—70'x16' Bridge
## Place—Branch, Mason Co. Mich.

| No. Pcs. | NAME | Mk. | Shipment No. | Shipment Date | Assem. Mk. | No. Pcs | SECTION | Ft. | Ins | Wght. per Ft. | WEIGHT | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Keg Bolts | | | | | 6 | $\frac{3}{4}$ M. Bolts | 1 | 0 | | 15 | For Trusses |
| | | | | | | 8 | $\frac{3}{4}$ Split Wedges | | | | 4 | List does not i |
| | | | | | | 32 | $\frac{5}{8}$ M. Bolts | 0 | $1\frac{3}{4}$ | | 14 | any bolts to ta |
| | | | | | | 140 | $\frac{3}{4}$ M. Bolts | 0 | $1\frac{1}{4}$ | | 91 | place of stripp |
| | | | | | | 140 | $\frac{3}{4}$ But. Hd. Bolts | 0 | $1\frac{1}{4}$ | | 20 | threads & lost |
| | | | | | | 336 | $\frac{3}{4}$ M. Bolts | 0 | $1\frac{1}{2}$ | | 217 | bolts.—No extra |
| 4 | Floor Bms. | | | | | 4 | 18" Is | 17 | 10 | 55 | 3923 | |
| | | | | | | 32 | $3 \times 2\frac{1}{2} \times \frac{3}{8}$ Ls | 1 | 3 | | 262 | |
| | | | | | | 32 | $3 \times 2\frac{1}{2} \times \frac{3}{8}$ Ls | 0 | 5 | | 86 | |
| | | | | | | 256 | $\frac{3}{4}$ Riv. Hds. | | | | 41 | |
| 2 | Wall Plates | | | | | 2 | 5" Ls | 15 | $6\frac{3}{8}$ | $6\frac{1}{2}$ | 204 | |
| 20 | Rails | | | | | 4 | 4" Ls | 11 | $10\frac{5}{8}$ | $5\frac{1}{4}$ | 369 | |
| | | | | | | 4 | 4" Ls | 10 | $6\frac{5}{8}$ | $5\frac{1}{4}$ | 222 | |
| | | | | | | 12 | 4" Ls | 13 | $11\frac{1}{4}$ | $5\frac{1}{4}$ | 877 | |
| | | | | | | 16 | $2\frac{1}{2} \times \frac{1}{4}$ Bars | 0 | $9\frac{1}{4}$ | | 26 | |
| 1 | Keg Bolts | | | | | 112 | $\frac{1}{2}$ M. Bolts | 0 | $1\frac{3}{4}$ | | 28 | |
| | | | | | | 48 | $\frac{1}{2}$ M. Bolts | 0 | $1\frac{1}{4}$ | | 12 | |
| | | | | | | 28 | $\frac{1}{2}$ M. Bolts | 0 | $1\frac{1}{2}$ | | 6 | |
| | | | | | | 8 | $\frac{1}{2}$ M. Bolts | 0 | 3 | | 3 | |
| | | | | | | 16 | $4 \times \frac{1}{4}$ Washers | 0 | 4 | | 18 | |
| 4 | Lat. Rods | | | | | 4 | $\frac{3}{4}$ φ | 22 | $0\frac{1}{2}$ | | 132 | |
| | | | | | | 6 | $\frac{3}{4}$ φ | 21 | 4 | | 181 | |
| | | | | | | 16 | $\frac{3}{4}$ Nuts | | | | 1 | |
| 25 | Bdls. Cor. Sheets | | | | | 245 | Cor. Sheets $28\frac{1}{2}$" x 26" | | | | | |

In order to work out the weights we find that the 70' X 16' bridge will apply. Using this bridge we take the end posts first. Their weight is 2134#. Section is made up of 2 - 8" - 11 1/4# channels with a top plate of 14 X 1/4 . The weight per foot runs 34.4#. Length of each post is 9.90. The section of the 65' bridge is made of 12 X 5/16 top plate, and two 7" - 12 1/4# channels, total weight per foot is 37.25. Length of post 9.2'. From proportion we have $\frac{2134 \times 37.25 \times 9.2}{34.4 \times 9.9} = 2144\#$ which is the weight of the end posts.

The top chord has the same sections as the end posts respectively. Weight of 70' bridge chords is 5220. Length of 70' span is 56'. Length of 65' is 52'. Hence $\frac{5220 \times 37.25 \times 52}{34.4 \times 56} = 5250\#$ weight of top chords.

The verticals weigh 479# in the 70' bridge, length 7'- 0. In 65', same section, 6'- 6.

Hence $\frac{479 \times 1 \times 6.5}{1 \times 70} = 445\#$ for verticals.

For the diagonals we have in the 70'-

| | | |
|---|---|---|
| 4 angles 2 1/2 X 2 1/2 X 5/16, first set, | weight per foot | 20.0 |
| 4 angles 2 1/2 X 2 1/2 X 1/4, second set, | weight per foot | 16.4 |
| 2 angles 3 X 2 1/2 X 5/16, third set, | weight per foot | 11.2 |
| Adding | - - | 47.6 |

For the 65' span, we get--

| | |
|---|---|
| 2 angles 5 X 3 1/2 X 5/16. first set, | 17.4 |
| 2 angles 4 X 3 X 5/16, second set, | 14.4 |
| 2 angles 3 X 2 1/2 X 5/16, third set, | 11.2 |
| Adding - | 43.0 |

The length of the diagonals in the bridges vary as 70 is to 65. Weight of diagonals in 70' is 2439#.

Hence $\frac{2439 \times 65 \times 43}{70 \times 47.6}$ = 2050#, weight of diagonal.

For lower chords, we get the 70' span,

| | | |
|---|---|---|
| 2 angles 3 1/2 X 2 1/2 X 5/16 | ------ | 12.2 |
| 2 angles 6 X 3 1/2 X 1/2 | --- -- | 30.6 |
| 1 angle 6 X 4 X 1/2 | ------ | 16.2 |
| | | 59.0 |

Note that for the center panel we use only half of the angle in order to keep the proportion.

For the 65' bridge,

| | | |
|---|---|---|
| 2 angles 3 X 2 1/2 X 5/16 | --- | 11.2 |
| 2 angles 5 X 3 1/2 X 1/2 | --- | 27.2 |
| 1 angle 6 X 4 X 1/2 | --- | 16.2 |
| | | 54.6 |

Now the lower chords vary in length as the span and the weight per lineal foot. Taking weight of 70' as 4638#.

$$\frac{4638 \times 65 \times 54.6}{70 \times 59.0} = 3980\#.$$

Extras ( bolts, etc.) 361 plus 67= 428#

$$428 \times \frac{70}{65} = 396$$

$$396 \times \frac{70}{65} = 368$$

$$\overline{764}$$

764 ÷ 2 = 382# or this is the mean between the spans and the square of the spans.

Floor beams are 18" - 55# I s in both cases, and are of the same length. There are four in each bridge. Hence we take the weight of the 70' span as given, which is 4312#. Same with the wall plates - 204#.

Railings 1494# $\times \frac{65}{70}$ = 1385#.

The stringers in the 70' weigh 11182#, and are 6 - 9" - 21# I s and 2 - 9" - 13 1/4# channels with two 2 X 2 X 1/4 angles on top. Hence for each foot of the span we would get :

| | |
|---|---|
| 6 X 21 = | 126 |
| 2 X 13.25 = | 26.50 |
| 2 X 3.2 = | 6.4 |
| | 158.9 |

In the 65' bridge we get

| | |
|---|---|
| 6 X 21 = | 126 |
| 2 X 15 = | 30 |
| | 156# per foot. |

$$\frac{11182 \times 65 \times 156}{70 \times 158.9} = 10180\# \text{ for stringers.}$$

Lateral rods in the 70' weigh 314# and

are 3/4" rounds and weigh 1 1/2#, in the 65' are 2 1/2 X 2 X 5/16 angles which weigh 4.5#. Varv as 21 is to 20.

$$\frac{314 \times 20 \times 4.5}{21 \times 1.5} = 895\#$$

Tie rods weigh the same, 85#.

Summing up, we get

| | |
|---|---|
| End Posts | 2144 |
| Top Chord | 5250 |
| Verticals | 445 |
| Diagonals | 2050 |
| Lower Chord | 3980 |
| Extras | 382 |
| Floorbeams | 4312 |
| Wall Plates | 204 |
| Railings | 1385 |
| Lateral Rods | 895 |
| Tie Rods | 85 |
| Stringers | 10180 |
| Estimated weight of structure | 31312 |

| | |
|---|---|
| 4% for scraps etc. | 1252 |
| Total weight | 32564 |

Estimated weight of the steel used in the structure 32600.

The above problem shows that in order to get the weights we use the ratios of the length of the known members to the estimated members and the ratio of the weight per foot of the main parts of the known members to the similar parts in the estimated member. The error that enters is offset by adding the percentage for scraps, etc. Some shows record the estimated weights for say six months and the actural weights and get a relation to be used for the next six months. This percentage would vary with different kinds of work, for instance in bins the percentage of scrap would be very large. However, this must be figured in relation to the shops where one is working.

The use of graphs is very useful to an estimator. For instance, one can plot the weights of a like nature and from the curves get any intermediate

weight near enough for making the stress calculations.

Again, from graphs it is readily seen that in cutting down, say from a 70' to a 65' we get a higher weight than in raising from a 60' to a 65'. The reason is that the details will run heavier in proportion to the main parts of a member in a longer bridge.

Conclusion--

No matter what the type of the structural job is, the same general method of estimating is used. The estimator has always to bear in mind the relation between the shops and the drafting department, the cost of the materials used, the amount of time for deliveries from the mill and then the figuring of the weight is a case of proportion.

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