# HIGHWAY BRIDGES IN WISCONSIN.

by

Bert E. Dodge

A thesis submitted to the Department of Civil Engineering and the Faculty of the Graduate School in partial fulfillment of the requirements for the degree of Civil Engineer.

1915.

Approved: H. A. Rice.
Department of Civil Engineering.

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A THESIS SUBMITTED TO THE FACULTY OF
THE SCHOOL OF ENGINEERING OF
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FOR

THE DEGREE OF CIVIL ENGINEER

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## PREFACE.

In this work the subject of Highway Bridges has been treated from a construction standpoint rather than from a theoretical or historical standpoint. Only such references to theory are made as are necessary to illustrate the standard practice, used by the author in his work for the Wisconsin Highway Commission.

A very valuable part of this work will be found in the tables showing weights of steel bridges, also types and cost of bridge work in the State of Wisconsin.

The chapter on office practice describes an efficient method of conducting the office end of a highway department.

Estimating is treated in a rather unusual manner but in a way which will give costs with only a small percentage of error if discretion is used.

Patents and legislation are of interest to every engineer and every state department. A description of present conditions with suggested improvements are explained in full.

Bert E. Dodge

Madison, Wisconsin

April , 1915.

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# INTRODUCTION.

The design and construction of highway bridges is becoming a science requiring the best skill and intellect of the engineering profession. The abominable practice of the early days when the contractor sold the town or county officials a bridge from a pencil sketch are fast passing out of existence and we now have in many of our states, laws requiring that plans be furnished by their State Highway Department, or approved by that body.

In Wisconsin the legislature of 1911 passed a law creating a state highway commission providing for a system of prospective state highways and the appointment of a county highway commissioner. An annual appropriation of $350,000 was made for the purpose of providing state aid in 1912 and succeeding years to those towns and counties which voted taxes for the improvement of any road or bridge on the system of prospective state highways. An appropriation of $40,000 was provided for the maintenance of the commission.

The legislature in 1913 amended the law so as to grant state aid to cities and villages having a population of less than 5000. The annual appropriation was increased to $1,200,000 and the appropriation for the support of the commission was to be $90,000 in 1913 and $100,000 annually thereafter.

The State Highway Commission consists of five members serving without salary and an efficient and competent engineering force, adequate to insure proper and uniform design for all bridges. The state law provides that all bridges shall be safe for loads up to and including fifteen tons without planking. The bridges built prior to the passage of this act were only designed for ten tons and many would only carry six tons with safety.

Under the state aid law 40 per cent of the cost of a bridge is paid by the town, 40 per cent by the county and 20 per cent by the state. The word "town" as used in Wisconsin means "township" or a subdivision of a county which is generally six miles square. Bridges are often built under the provisions of another law known as the " county aid law" which provides that 50 per cent of the cost of a bridge shall be paid by the town and 50 per cent by the county. Under either law the plans for bridges must be approved by the State Highway Commission.

To show the number of bridges actually built during the operation of the state aid law the following table will be of interest.

BRIDGES BUILT.

| | 1912 | 1913 | 1914 | Total |
|---|---|---|---|---|
| State Aid Bridges | 115 | 151 | 362 | 628 |
| County Aid Bridges | 235 | 276 | 382 | 893 |
| Total | 350 | 427 | 744 | 1521 |

## COST OF BRIDGES

| | 1912 | 1913 | 1914 | Total |
|---|---|---|---|---|
| State Aid Bridges | $89,420 | $141,940 | $427,260 | $658,620 |
| County Aid Bridges | 300,440 | 292,880 | 401,820 | 995,140 |
| Total | $389,860 | 434,820 | 829,080 | 1,653,760 |

All the work referred to in the above tables was designed by the commission's engineers and complete plans and specifications were furnished for every job.

The preceding tables show that almost as many bridges were built in 1914 as were built in the two preceding years and it is also shown that the average cost of a bridge in the state of Wisconsin is but little over $1000.

## TYPES OF STRUCTURES

Before discussing the relative merit of any particular type of construction it will be interesting to study the following table which shows the types built during the past three years.

## TYPE OF STRUCTURES

| Superstructures | 1912 | 1913 | 1914 | Total |
|---|---|---|---|---|
| I-Beam Spans | 188 | 238 | 415 | 841 |
| Reinforced Concrete Slabs | 85 | 122 | 202 | 409 |
| Riveted Trusses | 56 | 38 | 62 | 156 |
| Plate Girders | 4 | 11 | 42 | 57 |
| Through Concrete Girders | 8 | 11 | 11 | 30 |
| Deck Concrete Girders | 0 | 0 | 6 | 6 |

| Substructures | 1912 | 1913 | 1914 | Total |
|---|---|---|---|---|
| Mass Concrete | 169 | 248 | 449 | 866 |
| Reinforced Concrete | 76 | 93 | 214 | 383 |
| Steel Pile | 57 | 53 | 31 | 141 |
| Stone Masonry | 26 | 19 | 24 | 69 |
| Tubular Abutments | 13 | 7 | 20 | 40 |
| Arches | | | | |
| Reinforced Concrete | 6 | 4 | 5 | 15 |
| Stone Masonry | 3 | 3 | 1 | 7 |
| Span length in miles | 2.25 | 2.08 | 4.03 | 8.36 |

Attention is called to the fact that all of our bridge construction is of a permanent character. The life of steel spans may be roughly estimated at fifty years. The only maintenance expense necessary is to paint the steel thoroughly every three years and keep a wearing surface on the concrete floor. The wearing surface is not a great source of expense because two inches of gravel will give good service under moderate traffic and a two inch bituminous surface will serve effectively under heavy traffic.

From thirty to fifty years is as long as a highway bridge generally stands, because the traffic conditions change requiring new structures designed for heavier loading, with wider roadways and of more ornate appearance.

A description of each type of construction will now be given. The explanation which follows will only apply to bridges with concrete floors because all of our standard plans are designed on that basis. Other types of floors will be discussed in the latter part of this book.

## I-BEAM SPANS

The I-Beam span is the most popular for spans between 10 feet and 32 feet. We recommend this type of construction where poor material is likely to be used, where an incompetent builder will be in charge of the work, where foundations are uncertain and where the cost of a better type of construction is prohibitive. One objection to this type of bridge is the unsightly railing for which at the present time we are using two lines of three inch, four pound channels. The use of a gas pipe railing or a lattice railing has been considered but where used it has not been found preferable to the channel rail.

Standard plans have been prepared for this type of superstructure for sixteen feet, eighteen feet and twenty feet roadway in span lengths of ten feet to thirty-eight feet varying by two feet in length. Although we have designs for spans up to thirty-eight feet, it is generally desirable to use a plate girder for spans greater than thirty-two feet because the deflection of the heavier beams is quite noticeable.

The concrete floor design is the same for all spans, this being six inches at the center and five inches at the curbs. The reinforcement consists of one-half inch square bars at six inch centers transversely and two bars between adjacent beams longitudinally. No provision for expansion is made in these short spans.

A table giving complete information for I-beam spans follows:

16 Feet Roadway.

| Length of Span in feet. | I-Beams | | | Channels | | | Total wt. of steel including reinforcement. | Cu. yds. conc. in floor. |
|---|---|---|---|---|---|---|---|---|
| | Dept in inches. | Weight of one beam in lbs. per lin. ft. | No. | Depth in inches | Weight of one beam in lbs per lin. ft. | No. | | |
| 10 | 8 | 18 | 6 | 8 | 11¼ | 2 | 2290 | 3.2 |
| 12 | 8 | 18 | 6 | 8 | 11¼ | 2 | 2670 | 3.8 |
| 14 | 9 | 22 | 6 | 9 | 13¼ | 2 | 3350 | 4.4 |
| 16 | 9 | 21 | 6 | 9 | 13¼ | 2 | 3810 | 5.0 |
| 18 | 10 | 25 | 6 | 10 | 15 | 2 | 4730 | 5.7 |
| 20 | 12 | 31½ | 5 | 12 | 20½ | 2 | 5660 | 6.3 |
| 22 | 12 | 31½ | 6 | 12 | 20½ | 2 | 6910 | 6.9 |
| 24 | 12 | 31½ | 6 | 12 | 20½ | 2 | 7470 | 7.5 |
| 26 | 15 | 42 | 5 | 15 | 33 | 2 | 9250 | 8.2 |
| 28 | 15 | 42 | 6 | 15 | 33 | 2 | 11140 | 8.8 |
| 30 | 15 | 42 | 6 | 15 | 33 | 2 | 11890 | 9.4 |
| 32 | 18 | 55 | 5 | 15 | 33 | 2 | 13310 | 10.0 |
| 34 | 18 | 55 | 5 | 15 | 33 | 2 | 14100 | 10.6 |
| 36 | 18 | 55 | 6 | 15 | 33 | 2 | 16940 | 11.2 |
| 38 | 18 | 55 | 6 | 15 | 33 | 2 | 17840 | 11.8 |

18 Feet Roadway

| Length of Span in ft. | I-Beams | | | Channels | | | Total wt.of steel includ ing reinforc ement. | Cu.yds Conc.in Floor. |
|---|---|---|---|---|---|---|---|---|
| | Depth in inches | Weight of 1 beam in lbs per lin.ft | No. | Depth in inches | Weight of 1 Beam in lbs per lin.ft. | No. | | |
| 10 | 8 | 18 | 7 | 8 | 11¼ | 2 | 2560 | 3.6 |
| 12 | 8 | 18 | 7 | 8 | 11¼ | 2 | 2980 | 4.2 |
| 14 | 9 | 21 | 7 | 9 | 13¼ | 2 | 3750 | 4.8 |
| 16 | 9 | 21 | 7 | 9 | 13¼ | 2 | 4270 | 5.6 |
| 18 | 10 | 25 | 7 | 10 | 15 | 2 | 5300 | 6.3 |
| 20 | 12 | 31½ | 6 | 12 | 20½ | 2 | 6450 | 7.1 |
| 22 | 12 | 31½ | 7 | 12 | 20½ | 2 | 7760 | 7.7 |
| 24 | 12 | 31½ | 7 | 12 | 20½ | 2 | 8410 | 8.4 |
| 26 | 15 | 42 | 6 | 15 | 33 | 2 | 10530 | 9.2 |
| 28 | 15 | 42 | 7 | 15 | 33 | 2 | 12510 | 9.9 |
| 30 | 15 | 42 | 7 | 15 | 33 | 2 | 13350 | 10.5 |
| 32 | 18 | 55 | 6 | 15 | 33 | 2 | 15290 | 11.1 |
| 34 | 18 | 55 | 6 | 15 | 33 | 2 | 16210 | 11.8 |
| 36 | 18 | 55 | 7 | 15 | 33 | 2 | 19160 | 12.5 |
| 38 | 18 | 55 | 7 | 15 | 33 | 2 | 20190 | 13.1 |

20 Feet Roadway

| Length of Span in ft. | I-Beams | | | Channels | | | Total wt. of Steel includ ing reinforc ement. | Cu.yds. Conc.in Floor. |
|---|---|---|---|---|---|---|---|---|
| | Depth in inches | Weight of 1 Beam in lbs per lin.ft. | No. | Depth in inches | Weight of 1 Beam in lbs per lin.ft. | No. | | |
| 10 | 8 | 18 | 8 | 8 | 11¼ | 2 | 2830 | 4.0 |
| 12 | 8 | 18 | 8 | 8 | 11¼ | 2 | 3290 | 4.7 |
| 14 | 9 | 21 | 8 | 9 | 13¼ | 2 | 4150 | 5.5 |
| 16 | 9 | 21 | 8 | 9 | 13¼ | 2 | 4720 | 6.2 |
| 18 | 10 | 25 | 8 | 10 | 15 | 2 | 5890 | 7.0 |
| 20 | 12 | 31½ | 7 | 12 | 20½ | 2 | 7240 | 7.8 |
| 22 | 12 | 31½ | 8 | 12 | 20½ | 2 | 8630 | 8.6 |
| 24 | 12 | 31½ | 8 | 12 | 20½ | 2 | 9340 | 9.3 |
| 26 | 15 | 42 | 7 | 15 | 33 | 2 | 11810 | 10.1 |
| 28 | 15 | 42 | 8 | 15 | 33 | 2 | 13890 | 10.9 |
| 30 | 15 | 42 | 8 | 15 | 33 | 2 | 14830 | 11.6 |
| 32 | 18 | 55 | 7 | 15 | 33 | 2 | 17270 | 12.3 |
| 34 | 18 | 55 | 7 | 15 | 33 | 2 | 18300 | 13.0 |
| 36 | 18 | 55 | 8 | 15 | 33 | 2 | 21390 | 13.8 |
| 38 | 18 | 55 | 8 | 15 | 33 | 2 | 22530 | 14.5 |

Pages 14-16
do not exist

Encasing the beams in concrete has not been found necessary or desirable. If the beams are encased the concrete yardage is considerably increased, also the dead load. This requires heavier beams for the longer spans, and the increased life of the structure is not sufficient to warrant this initial expenditure.

Our specifications provide that the steel work shall be given three good coats of paint.

Many of these spans built with plank floors are giving good service to-day after twenty to thirty years use and the beams have not been painted since the structure was erected. However, the plank floors have prooved a constant source of expense and a renewal is required about every three years

Dalberg Bridge, Town of Akan, Richland County. A typical I-Beam bridge; span 28 feet; Roadway 16 feet. Cost $1200.

Sutters Bridge, Town of Paris, Grant County. An I-beam bridge with well riprapped streambed. Span 16 feet; Roadway 16 feet. Cost $571.

## PLATE GIRDER SPANS

Plate girders are the most desirable type of steel superstructures for spans from 35 feet to 80 feet. They make a very permanent type of bridge and a nice appearing structure. The weight of the girders make them difficult to erect where far from a railroad and inexperienced foremen have considerable trouble in erecting long girders without distorting them. Very often the cover plates are badly bent in shipping or erecting and sometimes the entire girder is bent out of line at least one-half inch. In spite of the objections just mentioned, the plate girder is most satisfactory when properly erected and we are getting better results the more we use them.

In shipping girders which extend over two cars, it is necessary to have the webs upright. A few girders were shipped last year laying flat on the cars and in every case these girders were distorted and bent.

The cost of plate girders is very little more than trusses and on several large jobs where alternate bids were taken the plate girders were considerably lower than the trusses.

In designing plate girders a minimum depth of web of 60 inches is used. This is done to avoid the use of a railing on top of the girders. Some excess metal is used in the shorter spans but the a ctual cost has not proven greater than where a shallower web and a railing is used. The top flange consists of two angles and a cover plate but the bottom flange consists of two angles only. The cover plate is necessary on the top flange for the sake of appearance but on the lower flange it was found difficult to remove the concrete from the rivet heads and get a good job of painting where a cover plate was used. This objection of course would only apply to through girders with a concrete floor built according to our detail.

We have recently prepared a set of plate girder designs for 16 feet, 18 feet and 20 feet roadway for span lengths from 35 feet to 80 feet, the designs varying by 5 feet in length.

The floor system consists of I-Beams placed transverse to the roadway. For a 16 feet roadway 10 inch beams are spaced at $3\frac{1}{2}$ feet centers, for an 18 feet roadway 12 inch beams are spaced at 4 feet centers and for a 20 feet roadway 12 inch beams are spaced $3\frac{1}{4}$ feet centers.

The concrete floor has the same dimensions as for the I-beam spans. The reinforcement consists of one-half inch square bars at six inch centers longitudinally and two bars between adjacent beams transversely. Provision for expansion is made by riveting a sole plate to the lower flange. This plate rests on a masonry plate and slotted holes are cut in the sole plate. The concrete floor is separated from the parapet wall of the abutment by two layers of tarpaper.

A table showing weights of steel for our plate girder spans follows:

Table Showing Weight in Pounds of Plate Girder Spans

16 feet roadway.

| Span in Feet. | Two Girders | Floor Beams | Reinforcement in floor. | Total weight of one span. |
|---|---|---|---|---|
| 35 | 9685 | 4550 | 1195 | 15430 |
| 40 | 10785 | 4975 | 1400 | 17160 |
| 45 | 12290 | 5800 | 1590 | 19680 |
| 50 | 13555 | 6220 | 1755 | 21530 |
| 55 | 15270 | 7035 | 1965 | 24270 |
| 60 | 17660 | 7515 | 2125 | 27300 |
| 65 | 20720 | 7960 | 2230 | 30910 |
| 70 | 25065 | 8795 | 2440 | 36300 |
| 75 | 28300 | 9630 | 2650 | 40580 |
| 80 | 31880 | 10050 | 2840 | 44770 |

## Table Showing Weight in Pounds of Plate Girder Spans

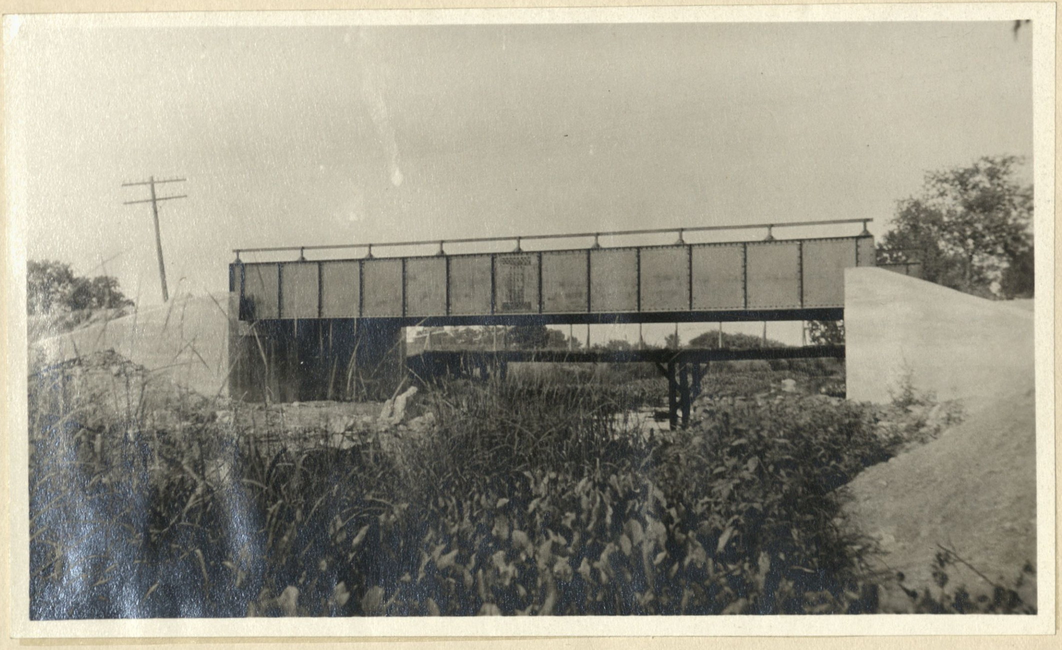
18 feet roadway.

| Span in Feet. | Two Girders | Floor Beams | Reinforcement in floor. | Total weight of one span. |
|---|---|---|---|---|
| 35 | 9600 | 5265 | 1285 | 16150 |
| 40 | 10760 | 5825 | 1525 | 18110 |
| 45 | 12180 | 7025 | 1735 | 20940 |
| 50 | 13875 | 7610 | 1915 | 23400 |
| 55 | 16410 | 8270 | 2120 | 26800 |
| 60 | 19170 | 8840 | 2300 | 30310 |
| 65 | 21540 | 9430 | 2420 | 33390 |
| 70 | 26390 | 10630 | 2660 | 39680 |
| 75 | 29865 | 11225 | 2870 | 43960 |
| 80 | 33460 | 11815 | 3085 | 48360 |

Table .Showing Weight in Pounds of Plate Girder Spans

20 feet roadway.

| Span in Feet. | Two Girders | Floor Beams | Reinforcement in floor. | Total weight of one span. |
|---|---|---|---|---|
| 35 | 9860 | 7120 | 1500 | 18480 |
| 40 | 10980 | 8420 | 1800 | 21200 |
| 45 | 12695 | 9065 | 2 000 | 23760 |
| 50 | 14765 | 10360 | 2235 | 27360 |
| 55 | 17120 | 11110 | 2470 | 30790 |
| 60 | 20170 | 12400 | 2700 | 35270 |
| 65 | 22930 | 13075 | 2835 | 38840 |
| 70 | 28510 | 14350 | 3100 | 45960 |
| 75 | 32140 | 15035 | 3335 | 50510 |
| 80 | 36310 | 16350 | 3600 | 56260 |



Fond du Lac Road Bridge, Town of Waupun, Fond du Lac county.

45 feet Plate Girder Span, 20 feet Roadway. Cost $2090.

A typical failure under a traction engine. Nobody was hurt.

## PONY TRUSSES.

Pony trusses are used for spans from 35 feet to 85 feet where the erection of a steel span is advisable and the plate girder span undesirable from a construction standpoint. These trusses are all of the Warren type and riveted entire. Floor beams are provided at the panel points and a reinforced concrete floor is carried on joists. The floor is similar in all respects to the floors previously described for I-Beam spans.

Provision for expansion is made by resting the sole plates on heavy masonry plates and providing slotted holes in the sole plates. The concrete floor at the expansion end is separated from the parapet wall by two layers of tar paper.

A few state highway departments are designing these bridges with floor beams at the one-half panel points and omitting the joists. This requires a very heavy concrete floor, generally ten or twelve inches. The increased dead load in the floor is too great to warrant this type of construction. I have checked up a large number of such designs against our standards and find that the use of joists and a light floor is considerably cheaper.

All trusses are of the box chord type, the top chord consisting of two channels and a cover plate. This makes a very rigid truss and combined with a rigid floorbeam connection and a concrete floor, provides sufficient rigidity to omit knee braces. To substantiate this design, we have never seen or had reported to us any failure or tendency toward transverse vibration in any of our trusses. A knee brace is an unsightly appearing device at best and should not be used where rigidity can be secured by some other means. The writer would not be misinterpreted as favoring the omission of knee braces on any type of truss except a box chord with rigid floor beam connection. On a tee chord truss, substantial bracing is absolutely necessary. Several tee chord trusses have been inspected by our department which were twisted three inches out of alignment because of the lack of suitable knee braces.

The weights of our standard riveted pony trusses are given in the following tables.

Table Showing Weight in Pounds of Pony Truss Spans

| 16 feet roadway. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Span in feet. | Two Trusses | Laterals | Floor Beams | Stringers | Railing | Rail Posts | Rein'mt In flr. | Wall Plates | Total Weight. |
| 35 | 5360 | 520 | 1930 | 4570 | 560 | 70 | 1430 | 190 | 14630 |
| 40 | 6270 | 590 | 1910 | 5260 | 640 | 70 | 1530 | 190 | 16460 |
| 45 | 7240 | 580 | 1940 | 6860 | 720 | 70 | 1820 | 190 | 19420 |
| 50 | 9460 | 690 | 2870 | 6580 | 800 | 70 | 1910 | 190 | 22570 |
| 55 | 10890 | 720 | 2900 | 8390 | 880 | 70 | 2190 | 190 | 26230 |
| 60 | 13080 | 740 | 2890 | 9150 | 960 | 70 | 2390 | 190 | 29470 |
| 65 | 15530 | 860 | 3870 | 8550 | 1040 | 70 | 2510 | 190 | 32620 |
| 70 | 17800 | 890 | 3850 | 10680 | 1120 | 70 | 2800 | 190 | 37400 |
| 75 | 19580 | 900 | 3860 | 11440 | 1200 | 70 | 3030 | 190 | 40270 |
| 80 | 22900 | 940 | 3850 | 12400 | 1280 | 70 | 3050 | 190 | 44680 |
| 85 | 26330 | 1050 | 4850 | 12960 | 1360 | 70 | 3390 | 190 | 50700 |

Table Showing Weight in Pounds of Pony Truss Spans

| 18 feet roadway. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Span in feet. | Two Trusses | Laterals | Floor Beams | Stringers | Railing | Rail Posts | Rein'mt In flr. | Wall Plates | Total Weight. |
| 35 | 5400 | 570 | 2500 | 5200 | 560 | 50 | 1610 | 230 | 16120 |
| 40 | 6410 | 590 | 2500 | 6100 | 640 | 70 | 1760 | 230 | 18300 |
| 45 | 7520 | 620 | 2490 | 7810 | 720 | 70 | 2050 | 230 | 21510 |
| 50 | 9860 | 740 | 3770 | 7630 | 800 | 70 | 2170 | 230 | 25270 |
| 55 | 11660 | 770 | 3800 | 9540 | 880 | 70 | 2490 | 230 | 29440 |
| 60 | 13860 | 790 | 3790 | 10410 | 960 | 70 | 2700 | 230 | 32810 |
| 65 | 16280 | 930 | 5100 | 9910 | 1040 | 70 | 2860 | 230 | 36420 |
| 70 | 18550 | 950 | 5070 | 12150 | 1120 | 70 | 3200 | 230 | 41340 |
| 75 | 21870 | 970 | 5030 | 13010 | 1200 | 70 | 3420 | 230 | 45800 |
| 80 | 24590 | 1000 | 5020 | 14400 | 1280 | 70 | 3490 | 230 | 50080 |
| 85 | 28060 | 1120 | 6430 | 14750 | 1360 | 70 | 3830 | 230 | 55850 |

Morrison Creek Bridge, Town of Brockway, Jackson County. A typical pony truss, span 80 feet, Roadway 16 feet. Cost $3323.

Tichigan Bridge, Town of Waterford, Racine County. Two 70 feet spans, 16 feet roadway, Pony trusses. Mass concrete abutments and Tubular pier. Cost $4104.

## HIGH TRUSSES.

Where the use of a long span is desirable the high truss can be used successfully. These should preferably be of the parallel chord Pratt type for spans from 90 feet to 128 feet and the curved chord Pratt for spans of greater length. These trusses should be riveted complete except at end bearings where it may be advisable to use a pin.

For highway work where insufficient supervision is given the erection crew the chances for a good job are very much better with riveted trusses than with pin connected trusses. The writer recently inspected a pin connected truss which, through the ignorance of the foreman, was erected with main members and counters reversed in position. One $\frac{3}{4}$ inch round bar has been carrying loads for eleven years which should have been carried by two 1 inch x $\frac{3}{4}$ inch bars. This bridge has carried moderately heavy highway traffic and has repeatedly been crossed by traction engines. Such errors could not occur with riveted trusses because the punching for rivets is such that a member can be used in its proper position only.

For spans 200 feet or longer it is advisable to subdivide the panels because the size of joist can be considerably reduced. In deciding the most economical panel length it is best to use a length which will stress the joists up to the working stress allowable under the specifications. For a concrete floor we do not like to space joists less than $2\frac{1}{4}$ feet nor more than $2\frac{3}{4}$ feet center to center of joists.

Roller bearings make a satisfactory provision for expansion provided the rollers are enclosed. Where rollers merely rest on the masonry plate, dirt soon fills in around the bearings, the rollers rust fast to the masonry plate and no expansion is possible. We have followed the practice of enclosing rollers in dust proof boxes and filling these boxes with a non-congealing oil. This insures ample provision for expansion under all temperatures and climatic conditions.

In designing a set of standards it is quite important that the weights be accurately computed.

The following tables show weights for our standard spans, 16 feet and 18 feet roadway:

Weight in pounds of High Trusses

| 16 feet roadway. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Span in feet | Two Trusses | Bracing | Portals | Laterals | Floor Beams | Joists | Railing | Rail Posts | Shoes | Wall Plates | Rein't in Floor | Total Weight |
| 90 | 22150 | 1800 | 1930 | 1800 | 4850 | 13730 | 1440 | 360 | 2700 | 260 | 3580 | 54600 |
| 96 | 24560 | 1800 | 1930 | 1870 | 4850 | 14880 | 1540 | 360 | 2700 | 260 | 3650 | 58400 |
| 100 | 26040 | 1800 | 2000 | 1900 | 5650 | 15500 | 1600 | 360 | 2700 | 260 | 3800 | 61610 |
| 105 | 28480 | 2400 | 2000 | 2140 | 5800 | 16000 | 1680 | 400 | 2700 | 260 | 4170 | 66030 |
| 112 | 32100 | 2400 | 2000 | 2400 | 5800 | 17360 | 1790 | 400 | 2700 | 260 | 4250 | 71460 |
| 120 | 38330 | 3000 | 2100 | 2620 | 7000 | 18300 | 1920 | 450 | 2700 | 260 | 4780 | 81460 |
| 128 | 41500 | 3000 | 2500 | 2750 | 7000 | 19840 | 2050 | 450 | 2700 | 260 | 4850 | 86900 |
| 140 | 45160 | 6000 | 2080 | 2870 | 7940 | 25200 | 2240 | 450 | 2700 | 260 | 5600 | 100500 |
| 150 | 49500 | 6260 | 2080 | 2980 | 7895 | 29775 | 2400 | 450 | 2700 | 260 | 5720 | 110020 |

Weight in pounds of High Trusses

18 feet roadway.

| Span in feet | Two Trusses | Bracing | Portals | Laterals | Floor Beams | Joists | Railing | Rail Posts | Shoes | Wall Plates | Rein't in Floor | Total Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | 24130 | 1970 | 2090 | 1940 | 6280 | 15620 | 1440 | 360 | 2700 | 290 | 4040 | 60860 |
| 96 | 26000 | 1970 | 2090 | 1990 | 6340 | 17280 | 1540 | 360 | 2700 | 290 | 4140 | 64700 |
| 100 | 27910 | 1970 | 2220 | 2020 | 7820 | 18000 | 1600 | 360 | 2700 | 290 | 4310 | 69200 |
| 105 | 30400 | 2650 | 2220 | 2300 | 7580 | 18220 | 1680 | 400 | 2700 | 290 | 4790 | 73230 |
| 112 | 34820 | 2690 | 2230 | 2360 | 7620 | 20160 | 1790 | 400 | 2700 | 290 | 4840 | 79900 |
| 120 | 40720 | 3360 | 2300 | 2850 | 8890 | 20820 | 1920 | 450 | 2700 | 290 | 5390 | 89690 |
| 128 | 34980 | 3360 | 2640 | 2920 | 8850 | 23040 | 2050 | 450 | 2700 | 290 | 5520 | 95800 |
| 140 | 47520 | 6450 | 2130 | 3070 | 10950 | 28700 | 2240 | 450 | 2700 | 290 | 6330 | 110830 |
| 150 | 51970 | 6680 | 2130 | 3140 | 10950 | 34500 | 2400 | 450 | 2700 | 290 | 6500 | 121710 |

Simmons Bridge, Town of Forest, Richland County. A typical High Truss: Span 90 feet, Roadway 16 feet. Cost $3950.

Pella Village Bridge, Shawano County. Two spans of 112 feet 16 feet roadway. Cost $8172.

Note the temporary bridge and dam.

Fisk Bridge, Town of Holcombe, Chippewa County. Two curved chord Pratt trusses; Span 140 feet; Roadway 16 feet; Cost $10274.

Hatfield Bridge, Town of Brockway, Jackson County. A three hinged Arch. Span 180 feet; Roadway 16 feet. Two approach spans of 20 feet. Fifty feet above streambed at center of span. Cost $4950. Built under Commission's supervision in 1912.

## REINFORCED CONCRETE SLAB BRIDGES.

The reinforced concrete slab is a desirable type of structure for spans from 6 feet to 24 feet provided good material is available or a good contractor can be secured to build the work. These bridges require careful forming and the steel must be placed exactly according to plans.

In constructing the floors of the longer spans it is generally advisable to drive a row of wood piles in the center of the span or build concrete pedestals upon which a center bent may rest. Substantial falsework is absolutely necessary for this type of construction.

Some state commissions are designing flat slab bridges for all spans up to 30 feet. We have found it more economical to use the girder type of construction for these longer spans. A curb is used on these bridges to serve as a protection to the railing. A concrete railing is built on these bridges, consisting of a 10 inch wall with a heavy coping on top and paneled to give an aesthetic appearance.

Drainage toward the curbs is provided by making the slab 1½ inches thicker in the center than at the curbs. One three inch drain is placed in the center of each span. This drain is set under the curb to prevent clogging.

Reinforced concrete Bridge of Flat Slab type. Town of Hortonia, Outagamie County. Span 12 feet, Roadway 20 feet. Cost $600.

The result of an incompetent builder. Gates Bridge, Town of Beetown, Grant county, built by local authorities without supervision. Span 10 feet, Roadway 20 feet; Cost $330.

## THROUGH CONCRETE GIRDERS.

Through concrete girders are used for spans from 25 feet to 40 feet. These bridges are very satisfactory for narrow roadways and where clearance is of some importance. Where several spans are built, it requires careful supervision to get the girders properly lined up. These spans are seldom used on roadways wider than 18 feet because cross girders are required to carry the floor. It is better to use a deck girder design throughout than to use through girders and carry the floor oncross girders as the forming is ra ther complicated.

Funkelein Bridge, Town of Christiana, Dane County. Through concrete girders, span 36 feet, roadway 18 feet, skewed 30 degrees. Cost $2340. This is a very easy type of structure to build on a skew. Note the crooked channel of the stream.

## DECK CONCRETE GIRDERS.

Deck concrete girder bridges are used for spans from 24 feet to 40 feet, wherever a wide roadway is necessary and clearance conditions will permit. For narrow roadways the through girder is best because the girders also serve as railings but on wide roadways where cross girders would be required, the deck girder has a place.

Where two or three spans are built we do not make any provision for expansion but reinforce the structure rigidly from end to end. This has proven very satisfactory for bridges 120 feet in length or less.

## ARCHES.

As a general rule arches are not recommended for short spans because they restrict the waterway too much. There are, however, some cases where arches of 20 feet or 30 feet span can be built economically, this being in a deep valley where filling will be placed over the arch to a considerable depth. Wherever waterway is of primary importance, the flat slab or girder type of construction will give more satisfactory results.

For moderate spans, 50 feet to 70 feet, the arch is a very desirable type of construction, and is perhaps the most graceful and ornate type of structure which can be designed.

## STONE MASONRY ARCHES.

Stone masonry arches are built only in localities where good stone is available and where concrete material would be excessively high. Without good inspection it is difficult to get the intrados of a stone arch laid out to the exact curves shown on drawings and they do not make a good appearance unless the centering is built to a true curve.

## CONCRETE ARCHES.

Only reinforced concrete is used in our designs because the steel is necessary to prevent cracks due to settlement of foundations, temperature changes and possible tension due to unusual loadings not anticipated in the design.

Black Ash Bridge, City of Algoma, Kewaunee County. Two 40 feet spans, 20 feet roadway. Cost $3634. A typical Reinforced concrete arch bridge, suitable for a city or village. An ornate structure at moderate cost.

## SUBSTRUCTURES.

For practically all substructures mass concrete is best adapted to our conditions in Wisconsin. Where stone is available we permit the use of the stone in rubble concrete. However, in most parts of the state there is abundant gravel deposits and gravel is generally used.

For high abutments and substructures for reinforced concrete superstructures, the reinforced concrete abutment is generally used. A big saving in material can be effected in this way and in certain localities the contract price for reinforced work is but little higher than for mass work.

Stone masonry is not used where it can be avoided. It is impossible to get as nice a job or as permanent with stone masonry and for this reason we generally specify that the stone shall be used in rubble concrete. Certain localities which have a good quality of stone and good stone masons can use this type successfully but as a general proposition the use of stone should be avoided. The cost is almost as great as for concrete work and it has no comparison for permanency or appearance.

Steel piles are used in substructures for steel superstructures in cases where foundations are extremely uncertain, where concrete material is expensive or where there is great danger of scour and wash.

Tubes are used for abutments and piers wherever concrete must be deposited through deep water and when there is not money enough available and conditions will not warrant the building of concrete piers.

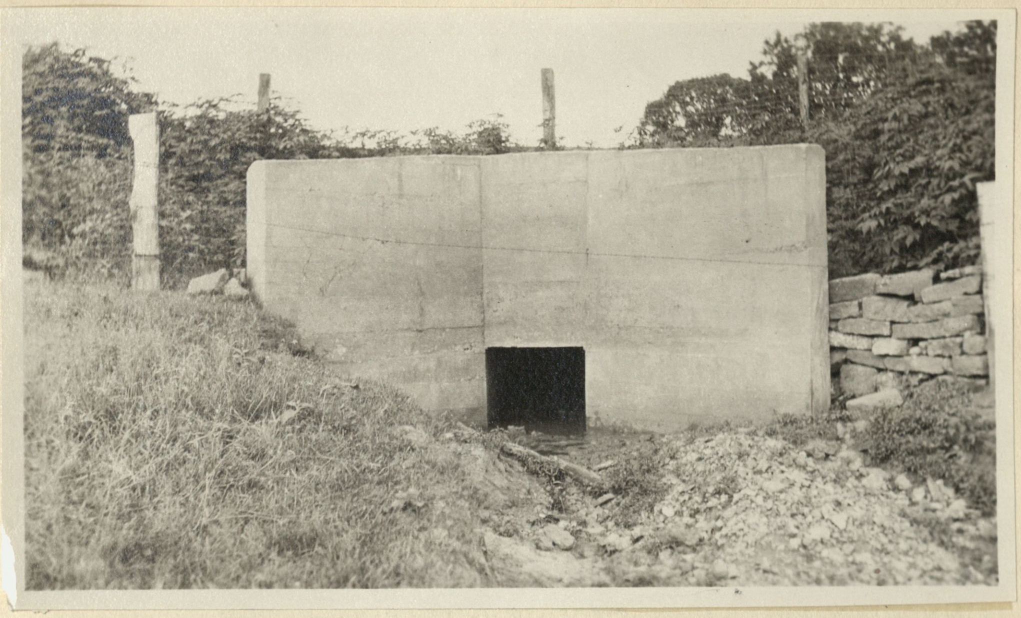
## CULVERTS.

The culverts which are now being built on state roads are of concrete of such design as best suit conditions. For small spans the end walls are built parallel to the roadway and carried high enough above the grade of the road to serve as a guard rail.

For larger spans the wing walls are built at an angle of 45 degrees with the road. This gives much shorter walls than is necessary if carried back parallel to the roadway.

Corrugated pipe culverts are sometimes used on new earth roads where there is great danger of settlement, and the roads are not well enough graded and drained to justify the expense of building permanent culverts.

Cast iron culverts have not been used because the initial cost is as great as for reinforced concrete, and the completed culvert is not as satisfactory either from the standpoint of appearance or permanency as concrete unless concrete end walls are built.



Hazen Culvert, Town of Mt. Ida; Grant County. A 3 feet x 3 feet Box culvert. Cost $248. End walls on these culverts are generally built parallel to the roadway and high enough above the road to serve as a guard.

TIMBER FLOORS.

Timber floors are seldom used for bridges in Wisconsin. The early bridges were built with plank floors but the maintenance expense is such as to make their use uneconomical unless a preservative treatment is resorted to. An ordinary three inch plank floor costs about $35 per thousand feet board measure in place and will give about three years service under ordinary traffic.

Creosote wood blocks laid on a creosote plank sub-floor makes a very desirable floor but is considerably more expensive than a concrete floor and requires more careful supervision in laying. The majority of bridge contractors are experienced in laying concrete floors but very few have had experience with wood blocks. Sometimes when laid under favorable conditions with a good inspector on the work, the blocks will heave during the winter and will have to be relaid the following spring.

## PAINT FOR STEEL BRIDGES.

The proper ingredients for paint are at the present time largely a matter of opinion. Sufficient tests have been made with red lead and pure boiled linseed oil to prove that this makes a very excellent preservative and our specifications provide that red lead shall be used in the proportions of 25 pounds red lead to one gallon of oil. The Kansas City Terminal Railway Company and other railway companies use 33 pounds of red lead to one gallon of oil. However, we have found that this makes a heavy stiff paint which is very hard to brush and for this reason a smaller amount of red lead is more easily applied.

The method of applying paint is almost as important as the ingredients. The surfaces must be dry and clean, free from rust or oil. The ordinary painter does not realize the importance of a clean surface and the result is blistered places and scale after a few months exposure to the weather.

## UNIFORMITY IN DESIGNS.

One admirable feature of a State Highway Department is uniformity of designs, thereby reducing the cost of fabricating steel bridges and simplifying the construction of concrete bridges.

For steel bridges where one set of standards are used, it is possible for shops to prepare sets of shop drawings and templates and fabricate duplicate designs from those drawings and templates.

In our work we may prepare plans for as many as twenty bridges in one year which have the same span length and the same width of roadway. The superstructure in each case being the same, the only change being in the substructure.

On concrete bridges it is often possible to move the forms from one job to another and thereby reduce the cost of building forms.

The earlier bridges built in this state possess no uniformity in design, the scheme in vogue at that time being for each contractor to submit his own plan. Sometimes one plan was adopted by the officials and bids received on this plan. In other cases each bidder placed a bid on his own design and the choice in designs was made after bids were opened.

Our department has measured several hundred of these old bridges in order to determine the capacity of the structure and report as to the advisability of repairing the old structure or the building of a complete new structure. In this way many peculiarities of design have been found.

Three inch and four inch gas pipe used to be used extensively for upper chords of pony trusses, generally for spans under fifty feet in length. I Beams bent to an elliptical curve have been used successfully for upper chords of long spans. A few structures have been found with Carnegie's special Tee's for upper chords.

Box chord trusses built of channels and cover plates are only to be found in the structures of comparatively recent date.

These old bridges were generally pin connected but a few cases have been found where castings were used of a peculiar shape to permit the hooking through of members without the use of pins.

In one case a pin connected truss bridge needed a new floor and the town officials engaged a local contractor to build a concrete floor on the structure. The bridge was probably designed to carry a ten ton road roller and a plank floor. All members had become loose and there was a great deal of vibration. After the concrete floor was built, the members became tight and all vibration ceased. The town officials thought they had discovered the proper cure for rattley bridges and were very much pleased. The dead load was far in excess of what the bridge was designed to carry and no doubt all members are stressed to double the values ordinarily used in bridge design.

WATERWAY

The waterway required for bridges in Wisconsin is a question which can generally be decided by judgment without the use or empirical formulas. Most of the country is well developed andbridges will be found over most of the streams. If a structure was too small at a certain site or washed out for any reason, it is generally possible to investigate the cause and to determine the exact size of span best adapted to this place.

A bad washout is often very misleading and unless the engineer makes a very careful examination of the site, the tendency is to build too large a span in such places. Sometimes a small culvert will back up the water to a great height, causing discharge under a head and eventually cutting out the road. I have seen a hundred feet of embankment washed out in such cases where a six feet culvert would carry the water under normal conditions and a twelve feet bridge would care for moderate floods.

WIDTH OF ROADWAY.

The width of roadway can only be determined after investigating the traffic conditions on a certain road.

For important roads all bridges should be 20 feet in width or wider, depending upon the location.

For moderately important roads, an 18 feet roadway is desirable and for side roads and roads of light travel, a 16 feet roadway is ample.

BRIDGE SURVEY.

Before attempting to prepare plans for any structure a survey of the site must be made in order to gather complete information regarding the structure.

The surveyor is instructed to get as complete information as possible and it requires a competent surveyor to gather all the information and make a complete report on the basis of his first visit.

The bridges are described by the local name by which they are commonly known; also by section, town and range. The road on which the bridge is located is described by giving the names of the cities connected.

If an old structure exists at the site a complete report of its condition is made and recommendations as to the feasibility of repairing the old structure also what material can be used in the new work, if repairing seems inadvisable.

Stream conditions are reported as accurately as possible, giving flood conditions, probable amount of drift carried and danger from ice.

In many cases, it is impracticable to bridge for flood conditions and in such cases it is desirable to construct a concrete overflow section on the road subjected to inundation. Any condition which may make construction difficult such as difficult foundations, difficulty in getting material to the bridge site or a liability to severe floods are reported.

Soundings are made with a one-half inch round rod, forced down as deep as possible and a report made as to what was encountered. In some cases test pits have been dug to rock but because of the variations in the rock strata we have been able to accomplish about as good results with the rod.

Cost data is secured on local material in order to estimate with reasonable accuracy the probable cost of the improvement.

A sketch is made showing the location of the bridge both in plan and in profile. If an instrument survey has been made of the road, the location of the center line and grade are referred to this survey. If no instrument survey has been made, the location of the new center line, and the elevation of bridge floor are decided in the field and marked.

The center line is marked by stakes on each side of the bridge and these are referenced by measurements at right angles to blazed trees or telephone poles. The measurement from one stake to the center of the span, or to one substructure unit, is also given.

The elevation of bridge floor is marked by a spike driven in a convenient tree or telephone pole at floor level.

After this information is secured the problam is ready for consideration in the office. The most desirable and economical type of structure is selected and plans are prepared upon that basis.

SPECIFICATIONS GOVERNING DESIGN.

In order to secure uniformity of design it was found necessary to prepare a set of general specifications governing the design of both steel and concrete structures. A wide deviation prevails among engineers regarding the distribution of a road roller loading. The distribution shown in our specifications is applicable to a concrete floor only and since very few timber floors are built it is applicable to practically all our work.

The specifications are believed to be of such practical value as to warrant their reproduction here in full. Parts of the specifications for steel bridges are taken direct from Cooper, but for our work it has been found a good, usable specification.

SPECIFICATIONS FOR STEEL BRIDGES.

Materials. The material in the superstructure shall be structural steel, except rivets, and as may be otherwise specified.

Span Length. The length of span shall be the distance center to center of bearings for trusses, girders and longitudinal beams; and the distance center to center of trusses for cross floor beams.

Head Room. For all through bridges there shall be a clear head-room of 15 feet above the floor, for a width of 5 feet on each side of the center line of the bridge.

Spacing of Trusses and Girders; The width center to center of trusses and girders shall in no case be less than one-twentieth of the effective span, nor less than is necessary to prevent overturning under the assumed lateral loading.

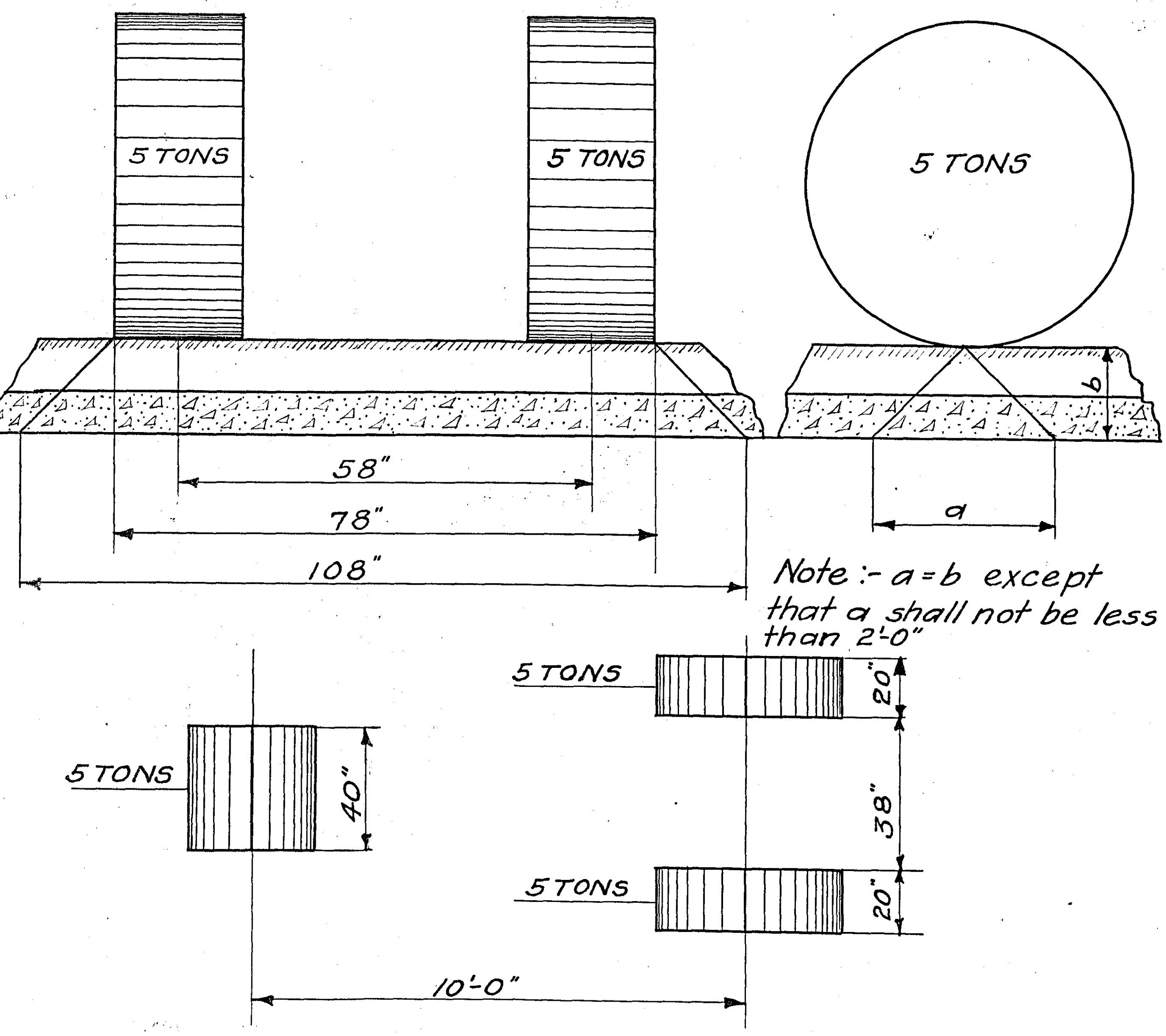
LOADING.

Dead Load. The dead load shall consist of the estimated weight of the entire suspended structure. Concrete will be assumed to weigh 150 pounds per cubic foot. Assume 2 inches of fill on floors of trusses, plate girders, and I beam spans. Fill to weigh 100 pounds per cubic foot.

Live Loads. For trusses and girders assume a uniform live load as shown in the following table.

| Span in feet | Pounds per sq. Ft. of floor surface. | Span in feet | Pounds per sq. Ft. of floor surface. |
|---|---|---|---|
| 40 or less | 125 | 115 | 85 |
| 45 | 122 | 120 | 82 |
| 50 | 120 | 125 | 79 |
| 55 | 117 | 130 | 77 |
| 60 | 114 | 135 | 74 |
| 65 | 112 | 140 | 71 |
| 70 | 109 | 145 | 69 |
| 75 | 106 | 150 | 66 |
| 80 | 104 | 155 | 63 |
| 85 | 101 | 160 | 61 |
| 90 | 98 | 165 | 58 |
| 95 | 96 | 170 | 55 |
| 100 | 93 | 175 | 53 |
| 105 | 90 | 180 | 50 |
| 110 | 88 | over 180 | 50 |

Floor Systems and Short Spans. For floor systems and spans under 40 feet a 15 ton road roller as shown below:




Note:- Consider load of roller concentrated on a line at the point of contact which is 108 inches for rear wheels and 54 inches for front wheel.

Impact. No allowance will be made for impact.

Lateral and Sway Bracing. To provide for wind and vibrations the top lateral bracing in deck bridges, and the bottom lateral bracing in through bridges, shall be proportioned to resist a lateral force of 300 pounds for each foot of span; 150 pounds of this to be treated as a moving load. The bottom lateral bracing in deck bridges, and the top lateral bracing in through bridges, shall be proportioned to resist a lateral force of 150 pounds for each linear foot.

Trestle Towers. In trestle towers the bracing and columns shall be proportioned to resist the following lateral forces, in addition to the strains from dead and live loads: The trusses loaded or unloaded, the lateral pressures specified above; and a lateral pressure of 100 pounds for each vertical foot lineal of the trestle bents.

Temperature. Variation in temperature, to the extent of 150 degrees Fahrenheit, shall be provided for.

Proportions and Unit Stresses: All parts of the structure shall be proportioned in tension by the following allowed unit stresses net sections.

For Medium Steel.

| | Pounds per square inch. |
|---|---|
| Floorbeam hangers, | 8000 |
| Longitudinal, lateral and sway bracing, for lateral forces, | 18000 |
| Longitudinal, lateral and sway bracing, for live load, | 15000 |

Rolled Beams, used as stringers or floorbeams 16000

| | (for live loads) | (for dead loads) |
|---|---|---|
| Bottom flanges of plate girders, chords, and webs of lattice and pin connected trusses,----------- | 12500 | 25000 |

For swing bridges and other movable structures, the dead load unit stresses, during motion must not exceed 3/4 of the above allowed unit strains for dead load or stationary structures.

Net Section. In proportioning tension members the diameter of the rivet holes shall be taken 1/8 inch larger than the nominal diameter of the rivet.

When but one leg of a single angle is riveted to its connection the section of that leg only will be considered as effective in tension.

Compressive Strains. Compression members shall be proportioned by the following allowed unit strains.

For Medium Steel.

Chord Segments P=12000 -55 l/r for live load strains.
P=24000 - 110 l/r for dead load strains.

Posts of through bridges including end posts,
P=10000 - 45 l/r for live load strains.
P=30000 - 90 l/r for dead load strains.

Posts of deck bridges including end posts,
P=11000 - 40 l/r for live load strains.
P=22000 - 80 l/r for dead load strains.

Lateral struts and rigid bracing,
P=13000 - 60 l/r for lateral forces.
For live load strains use 2/3 of above.

P = the allowed strain in compression per square inch of cross section in pounds.

r = the least radius of gyration of the section in inches.

l = the length of member, in inches.

Limiting Lengths of Members. No compression member shall have a length exceeding 120 times its least radius of gyration for main members, or 140 times its least radius of gyration for laterals.

Shearing. Shop driven rivets and pins 10000 pounds per square inch. Field driven rivets and bolts 7000 pounds per square inch. Plate girder webs, gross section 10000 pounds per square inch.

Bearing. Shop driven rivets and pins 20000 pounds per square inch. Field driven rivets and pins 14000 pounds per square inch. Expansion rollers per linear inch 400 d Where "d" is the diameter of the roller in inches. On masonry, 400 pounds per square inch.

Depth Ratios. Trusses shall have preferably a depth of not less than one-tenth the span. Plate girders shall have a depth of not less than one-twelfth the span. Rolled beams used as girders shall have a depth of not less than one-twentyfifth the span. If shallower trusses, girders or beams are used the section shall be increased so that the maximum deflection will not be greater than if the above limiting ratios had not been exceeded.

Plate Girders. Plate girders shall be proportioned by assuming that the flanges are concentrated at their centers of gravity. One-eighth of the gross section of the web may be used as flange section. The compression and tension flange shall have the same gross section.

Flange Rivets. The rivet spacing in the flange of girders will be determined by the following formula: P = d x b / S

where P = rivet spacing in inches.

d = distance center to center of rivets in flanges.

b = bearing value of a rivet in web unless web is of such thickness that bearing value is greater than double shear when the latter should be used.

S = shear at the point where it is desired to find the rivet spacing.

Web Stiffeners. There shall be web stiffeners in pairs over bearings. The spacing of stiffeners shall not exceed the depth of the web with a maximum limit of 6 feet. All stiffeners must be capable of carrying the maximum vertical shear without exceeding the allowed unit stress. P = 12000 - 55 l/r.

Rivets in End Stiffeners. There should be rivets enough in end stiffeners to transfer the shear in the web to the stiffeners over the sole plates. If the girder has two pairs of stiffeners over the sole plates, all the rivets in both stiffeners may be counted.

Stays for Top Flanges. Through plate girders shall have their top flanges stayed by knee braces or gusset plates at each end of floorbeams; the maximum spacing to be 12 feet.

Thickness of Metal. No material shall be used less than five-sixteenth of an inch thick, except for filling or unless otherwise specified.

Shear. Plate girder shearing stresses shall always be carried by the web alone.

Web Splice For Girders. All girder web plates shall be spliced on both sides. The splice shall be strong enough to transmit the full shearing strain and shall not have less than two rows of rivets on each side of the splice.

When part of the web is counted as flange area there shall be in addition to the number of rivets required to take the shear, sufficient rivets as near each flange angle as practicable to take the proportional part of the flange stress taken by the web.

To determine the number of rivets required to carry the shear; divide the maximum shear at the section by the bearing value of one rivet in the web. This will give the number of rivets required on each side of the splice.

To determine the net area of splice plates and number of rivets required to develop these; Net area of two splice plates equals the area of web used as flange area, multiplied by the ( effective depth of the girder)$^2$ and divided by the (distance center to center of splice plates)$^2$.

The number of rivets required equals the net area of two splice plates multiplied by the unit stress in flanges and divided by the bearing value of one rivet in web plate.

The number of rivets and area of plates requirerd to splice one-eight the web is the same whether the splice occurs near the end or near the center of the girder.

Flange Splices in Girders. Make flange angles and cover plates full length of girder where practicable.

Splices in angles where used should be as far apart as possible and on opposite sides of the web.

When possible the angle should be spliced with an angle the same area as the angle spliced and the splice angle extended on each side of the splice to take rivets enough to develop the angle, rivets in the web leg to be figured in bearing and rivets in the flange leg in shear.

If a field splice is necessary make splices as compact as possible.

Rolled Beams. Rolled beams shall be calculated by moments of inertia.

Symmetry of Sections and Connections. All details of connections and attachments shall be so designed that the strains coming on each member can be correctly calculated. The center line of strains shall coincide with the neutral axis of each member and intersect at the joint point as nearly as possible.

Sections to be symmetrical wherever possible.

Drainage. Provision shall be made for drainage, precaution being taken to have drip clear all parts of the metal work.

Access for Painting. As far as possible all parts of the structure shall be made accessible for cleaning, painting and inspection.

Strength of Connections. All connections and details of members shall be strong enough to break the body of the member.

Long Members. All long tension members shall be supported at suitable intervals to avoid rattling and undue stress by bending.

Splices in Compression Members. In compression members, abutting joints with planed faces must be sufficiently spliced to prevent lateral displacement. Abutting joints with untooled faces must be fully spliced.

Compression joints shall be placed as near as possible to points of support.

Depth of Bracing. The sway and portal bracing shall be as deep as clearance will allow.

Rivet Spacing. The distance from the center of the rivet hole to the edge of any piece shall not be less than one and one-half times the diameter of the hole nor exceed eight times the thickness of the plate. In shapes this distance shall conform to Carnegie's standard spacing. The pitch of rivets shall not be less than three diameters of the rivet hole nor more than six inches in the line of strain, or 16 times the thinnest outside plate.

Rivet Pitch at Ends. The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivets, for a length equal to twice the maximum width of member.

Size of Rivets. Three quarter inch diameter rivets shall be used in preference to other sizes.

Expansion Bearings. All spans of 90 feet or over shall have at one end, nests of steel expansion rollers. All spans less than 90 feet shall have one end free to slide on bearing plates.

Camber. In all trusses with parallel chords the camber shall be effected by making the top chords 1/8 inch longer for every 10 feet in length. Plate girders shall have a camber of 1/16 inch per 10 feet of length.

Counters. Whenever the live and dead load strains are of opposite character, only 70 per cent of the dead load shall be considered as effective in counteracting the live load strain.

Inclination of Lattice Bars. Single lattice bars shall generally be at 60 degrees and double bars at 45 degrees with the axis of the member.

SPECIFICATIONS GOVERNING THE DESIGN OF CONCRETE STRUCTURES

Loads. a. Dead Load. The Dead load shall include the weight of the structure and the fill on the floor also.

b. Live Load. The live load shall consist of a 15 ton road roller with distribution shown in specifications for steel bridges.

Girder spans 40 feet and up shall be designed for the uniform live loads shown in specifications for steel bridges.

All floor systems shall be designed for the roller loading. Sidewalks shall be designed for a uniform live load of 80 pounds per square foot.

Span Lengths. The span length of beams and slabs shall be taken as the clear length plus the depth of the beam or slab, except that it shall not, in any case, exceed the clear span plus two feet.

For floor systems of through and deck girder bridges the span length of slabs and cross girders will be taken as the distance center to center of girders.

Internal Stresses. The internal stresses are to be calculated upon the basis of the following:

a. The ratio of the moduli of elasticity of steel and concrete shall be taken as fifteen (15.).

b. The tensile stresses in concrete are neglected in calculating the amount of résistance in beams or slabs.

c. The depth of the beam is the distance from the compressive face to the centroid of the tensile reinforcement.

d. The effective depth of a beam at any point is the distance from the centroid of compressive stress to the centroid of tensile reinforcement.

e. The maximum shearing unit stress in beams is the total shear at the section divided by the product of the width of the section and the depth of the section considered. This shearing stress is to be used in place of the diagonal tensile stress in the calculation for web stresses.

Web Stresses. When the maximum shearing stresses exceed a value of thirty pounds per square inch, web reinforcement must be provided to aid in carrying the diagonal tensile stresses. This web reinforcement shall consist of bent bars inclined at 45 degrees with the horizontal and securely wired to the horizontal reinforcement to insure against slip. In the calculation of web reinforcement, proceed as follows: Divide the total shear on any section by the product of the depth of the beam and width of same, this will give the actual unit shear on the section. Assume that this unit shear will act on a plane making an angle of 45 degrees with the vertical and see that enough tensile reinforcement is put across the plane to take care of the shear, less 30 pounds per square inch, allowable in the concrete. Care should be taken to see that the diagonal tension bars have sufficient length above the neutral axis to develop the (actual) tensile unit stress in bond. If impracticable to use inclined reinforcement, use veftical stirrups as provided in general notes.

T-Beams. The width of slab to consider a part of the beam shall be determined by the following rules.

a. It shall not exceed one-fourth of the span length of the beam.

b. Its overhanging width on either side of the web shall not exceed four times the thickness of the slab.

Working Stresses. The following unit strësses in pounds per square inch are to be used.

a. High carbon steel in tension, 16000 pounds per square inch.

b. Steel in compression 15 times the compressive stress of the surrounding concrete.

c. Concrete in bearing 1:2:4 mixture 700 pounds per square inch.

d. Concrete in bearing 1:3:6 mixture 600 pounds per square inch.

e. Concrete in compression (columns reinforced as baskets) 1:2:4 mixture 800 pounds per square inch.

f. Concrete compression on extreme fibre 1:2:4 mixture 700 pounds per square inch.

g. Concrete in compression on extreme fibre 1:3:6 mixture 600 pounds per square inch.

h. Concrete in pure shear only 200 pounds per square inch.

i. Concrete in shear where shearing stress is used as the measure of diagonal tensile or web stresses, 30 pounds per square inch.

j. The limit of shearing stress in concrete where it is used as a measure of diagonal tension, even when reinforced with bent bars or stirrups, 120 pounds per square inch.

k. Bond value on bars 130 pounds per square inch.

<u>General Notes.</u> Reinforcement is to be protected with two inches of concrete unless otherwise specified. The minimum is to be one inch plus the diameter of the bar from the center of bar to lower face of slab.

Bars are to have a minimum spacing of $2\frac{1}{2}$ diameters center to center and not less than $2\frac{1}{2}$ inches.

In deciding size of reinforcement the smaller bars are to be preferred on account of the better distribution, and of their availability as shear reinforcement, alternate through and shear bar spacing is the preferable arrangement.

Shear bars should be so arranged that they overlap each other, so that the upper end of the shear bar nearest the center of the span should be above and beyond the bend in the second shear bar from the center of the span, the foregoing to apply throughout the structure. Where bars cannot be spaced to turn up as shear bars, stirrups passing under and firmly wired to main reinforcing bars should be used.

The maximum distance center to center of shear bars in the same plane should not be greater than the thickness of slab nor more than 2 feet.

Lay all bars so as to develop the tensile unit stress in bond.

Weights of material to be used in design.

| | |
|---|---|
| Asphalt | 90 pounds per cubic foot. |
| Brick | 120 pounds per cubic foot. |
| Concrete | 150 pounds per cubic foot. |
| Earth | 100 pounds per cubic foot. |
| Masonry | 165 pounds per cubic foot. |
| Sand | 100 pounds per cubic foot. |
| Steel | 490 pounds per cubic foot. |
| Timber | $4\frac{1}{2}$ pounds per foot board measure. |
| Wood Paving | 65 pounds per cubic foot. |

ABUTMENTS.

<u>For I-Beam Spans</u>. The top of wing walls shall be 12 inches wide in preference to other widths. The distance from top of curb to bridge seat shall be twenty-one inches for spans from 10 feet to 18 feet inclusive. The distance from top of curb to bridge seat shall be 2 feet for spans from 20 feet to 38 feet inclusive.

<u>For Plate Girder Spans</u>. Provide 16 inches bearing from face of coping to end of girder, leave 3 inches between end of girder and parapet wall and provide a 7 inch parapet giving a total width at bridge seat level of 26 inches. The length of bridge seat along the face of abutment shall be as follows:

For spans 35 feet to 55 feet inclusive, 16 feet roadway, 18 feet 4 inches.

For spans 60 feet to 70 feet inclusive, 16 feet roadway, 18 feet 8 inches.

For spans 75 feet to 80 feet inclusive, 16 feet roadway, 18 feet 10 inches.

For spans 35 feet to 50 feet inclusive, 18 feet roadway, 20 feet 4 inches.

For spans 55 feet to 65 feet inclusive, 18 feet roadway, 20 feet 8 inches.

For spans 70 feet to 80 feet inclusive, 18 feet roadway, 20 feet 10 inches.

The distance from top of curb to bridge seat shall be as follows:

For spans 35 feet to 60 feet inclusive, 16 feet roadway, 1 foot 9 inches.

For spans 35 feet to 60 feet inclusive, 18 feet roadway, 2 feet 0 inches.

For spans 65 feet to 75 feet inclusive, 16 feet roadway, 2 feet 3 inches.

For spans 65 feet to 70 feet inclusive, 18 feet roadway, 2 feet 3 inches.

For spans 75 feet, 18 feet roadway, 2 feet 9 inches.

For spans 80 feet, 16 feet roadway, 2 feet 9 inches.

For spans 80 feet, 18 feet roadway, 3 feet 3 inches.

SLAB SUPERSTRUCTURES.

The width of bridge seat shall be as follows:

For spans 6 feet to 14 feet, inclusive, 1 foot 0 inches.

For spans 16 feet to 18 feet inclusive, 1 foot 3 inches.

For spans 20 feet , 1 foot 6 inches.

For spans 22 feet to 24 feet, inclusive, 1 foot 9 inches.

The distance from top of curb to bridge seat shall be as follows:

For span 6 feet, 1 foot 3 inches.

For spans 8 feet to 10 feet inclusive, 2 feet 0 inches.

For spans 12 feet to 14 feet inclusive, 1 foot 9 inches.

For spans 16 feet to 18 feet inclusive, 2 feet 3 inches.

For spans 20 feet, 2 feet 6 inches.

For spans 22 feet to 24 feet inclusive, 2 feet 9 inches.

FOR TRUSSES.

The distance from top of curb to bridge seat shall be as follows:

For spans 35 feet to 85 feet inclusive, 1 foot 9 inches.

For spans 90 feet to 150 feet inclusive, 2 feet 9 inches.

The length of bridge seat along the face of abutment shall be as follows:

For spans 35 feet to 65 feet inclusive, 16 feet roadway, 19 feet 8 inches.

For spans 70 feet to 85 feet inclusive, 16 feet roadway, 20 feet 0 inches.

For spans 90 to 150 feet inclusive, 16 feet roadway, 21 feet 0 inches.

For spans 35 feet to 60 feet inclusive, 18 feet roadway, 21 feet 8 inches.

For spans 65 feet to 85 feet inclusive, 18 feet roadway, 22 feet 0 inches.

For spans 90 feet to 150 feet inclusive, 18 feet roadway, 23 feet 0 inches.

The bridge seat dimensions shall be as follows: For spans 35 feet to 85 feet inclusive, place center line of bearing 12 inches from face of coping, provide 10 inches between center line of bearing and parapet wall, make parapet wall 7 inches. Total width of bridge seat 2 feet 5 inches. For spans 90 feet to 150 feet inclusive, place center line of bearing 1 foot 6 inches from face of coping, provide 1 foot 6 inches between center line of bearing and parapet wall, make parapet 7 inches. Total width of bridge seat 3 feet 7 inches.

## OFFICE PRACTICE.

The success of any engineering project depends to a great extent upon the efficiency, ability and dispatch with which it is carried out. In highway work, and especially under the Wisconsin organization, there is a mass of detail work to handle, and in order that the numerous requests for advice, estimates, plans and specifications may be complied with, it has been necessary to systematize and standardize the work as much as possible.

The writer believes that his experience in supervising the preparation of plans and specifications for 1200 highway bridges will be of value to engineers engaged in similar work with similar problems to solve.

Fellowship. Fellowship or good feeling between the engineers in charge and subordinate employes is absolutely necessary for efficient work. One dissatisfied or disloyal employee can do more toward disrupting an organization than the mistakes of a dozen incompetent employees.

This was most forcibly brought to my attention several years ago while engaged in railway work. One man was employed to keep general supervision over the office and report any changes or improvements in the work which he might deem advisable. As a matter of fact most of his time was spent in talking with the men and creating an unfavorable sentiment toward the engineers in charge. This created a tendency toward loafing, carelessness and general dissatisfsction.

Our Bridge Engineer's policy has been to maintain a good feeling among his employees. This has been done by entrusting certain work to an individual and holding him strictly accountable for the proper execution of that piece of work.

Time. In a drafting office it is difficult to estimate just how much time a man should spend on a piece of work, because every problem has its own difficulties and it may not be possible to determine in advance just how complete an analysis may be necessary or how much detailing will be required. This, of course, to a certain extent, is a matter of experience and practice. The greatest time saver is for the men in charge to decide what will be done before making complete detail drawings. We follow the practice of making pencil sketches on tracing paper, blocking out the whole proposition before attempting to make detail plans for any structure. A few hours spent in this way may save two weeks in the preparation of drawings for an important proposition. In one office where I worked I have seen an entire month wasted by a squad of eight men, due to the fact that the engineer in charge would not take an hour at the proper time to examine the proposition and decide on what type of structure was best adapted to the particular site in question.

Designing. All designing is done in accordance with the specifications previously given. In originally starting a problem the draftsman is furnished a report on the structure which we have designated a survey report. Such sketches as are necessary for laying grades and deciding on span length and type of structure are made on profile paper or tracing paper as may seem best. A mathematical analysis may now be made. All computations are kept in bound books on cross section paper. If computations are made on loose sheets they may become separated or a sheet may be lost, and for this reason we have found it more satisfactory to use a bound computation book. Allcomputations are checked before the drawings are made. The computation books are all indexed so it is possible to refer to the original design for a structure at any time.

In analyzing arches we have followed the method outlined in Taylor and Thompson's book entitled " Concrete Plain and Reinforced".

For mass abutments and retaining walls under 15 feet in height we empirically make the base width equal to one-third of the height above the footing. An offset of six inches is usually made on both front and back for the footing and the footing is generally carried to a depth of three or four feet below the battered work. For heights greater than 15 feet an analysis is generally made using the formula $P = 1/2\ W\ H^2 \frac{1 - \sin\theta}{1 + \sin\theta}$ where P = the horizontal earth pressure against the wall. Assuming $\theta$ to be 30 degrees, and W equals 100 pounds, we have the simplified formula of $P = 16\ 2/3\ H^2$ for the horizontal pressure on the back of the wall. This pressure is assumed to act at a height of $\frac{H}{3}$ from the base, where H equals the total height of the wall.

Reinforced walls are always given a careful analysis using the theory previously outlined for earth pressure. A safety factor against overturning of two is used as a minimum on this work.

In designing flat slab bridges the ends are considered as fixed but the conservative coefficient of $\frac{1}{10}$ is used for dead load bending moment. For the live load, the maximum moment from the road roller is figured the same as for a slab with free ends and then multiplied by $\frac{8}{10}$. This places the live load computations on the same basis as the dead load and gives conservative results. The shear in our flat slab bridges does not exceed that allowable in the concrete and is not given any special consideration.

The floor system of through girder spans is designed for the road roller or for 200 pounds per square foot and the maximum moment is used. The girders are designed for the roller loading or 125 pounds per square foot and the maximum moment is used.

Deck girder spans are figured as T-Beams with the same live load assumptions as described for through girders.

All concrete spans are designed to carry one foot of gravel fill or 100 pounds per square foot. The reason this depth of fill is used is to permit macadamizing or paving across the smaller spans so that no break will occur in the surfacing at the bridge. If the road is surfaced with one material and the bridge floor with another there is apt to be a noticeable chuck or jolt in driving along the road because the two materials do not bond or have a different coefficient of wear.

Drawings. Where possible all drawings are made to two standard sizes, 8½ inches x 14 inches or 14 inches x 20 inches. The smaller sheet is used for all steel superstructures because it is small enough to bind in the contract form. We have found it much more satisfactory to bind the drawings, specifications, contract and bond forms together, making one compact manuscript. For important structures where larger drawings are necessary we use a size of 28 inches x 36 inches where possible.

For steel bridges only strain sheets are prepared. Because of the large number of shops fabricating our work it would be very difficult to prepare a shop drawing which would be usable in all shops. In fact, all shops prefer to prepare their own shop drawings. These are submitted to our office in duplicate and checked complete. All connections, rivet spacing, edge distances and general notes must conform with our standard practice and specifications. If the drawings are found satisfactory, one copy is stamped approved and returned to the fabricator, the other copy is retained for our files.

Tracing cloth is used for making all finished drawings. The Imperial brand has proven the most satisfsctory and best adapted to our work. Higgins'waterproof ink is used in preference to other inks.

Drafting requires considerable practice and where a number of draftsmen are employed careful supervision is necessary to secure uniformity of dra wings.

Specifications. Standard specifications have been prepared which can readily be adjusted to any particular structure. Where necessary these are supplemented by a special specification written especially for a particular structure and covering the points omitted on the standard specifications.

Reports. Blank forms have been prepared for practically all of our reports. In order that our records be complete for any particular structure we should have the following information:

1. A copy of the town's petition for state aid on state aid work.

2. A bridge survey report.

3. A copy of the plans and specifications and a copy of the contract on contract work.

4. A requisition for the transfer of state funds on state aid work.

5. A final inspection report.

6. A copy of formal acceptance made by the Bridge Engineer.

7. The County Highway Commissioner's statement of bridges built each year for state aid work.

A quite simple bookkeeping system has been perfected which is an account with each municipality doing bridge work in the state. This book shows the money available and the source. A debit and credit account is kept with each municipality charging out the work done. In this way is is possible to tell instantly the financial standing of any one of the 1210 towns of the state as far as their bridge work is concerned.

Filing System. In order to answer any question which may arise regarding any bridge in the state it was found necessary to perfect a convenient filing system. Very often a contractor or town chairman will lose his copy of plans and will telephone the office to find the quantity of material required, the estimated cost, depth to rock or any one of a hundred questions which might be asked about bridges. In filing all reports, contracts, correspondence or shop drawings the county has been made the unit for filing. For drawings a county index card system is kept which shows the drawing numbers for each municipality in a county.

We have at present about 1500 tracings and the filing of these in order that any tracings can be found instantly requires a carefully worked out system. All drawings are filed in drawers; the drawer for each class of work being plainly labeled, and the drawings are filed flat in numerical order. The drawings which are too long to file flat are rolled and indexed and the file number marked on the ends of the roll.

Because of the large number of duplicate designs for which we furnish plans it is necessary to keep about 5000 blueprints in stock all the time. Blueprints are much harder to file than tracings. For this purpose we have a specially built case with pigeon holes of suitable size. These are all properly indexed and filing is done according to numerical order.

For estimating purposes a sheet has been prepared showing probable cost under ordinary conditions of every standard superstructure which we have designed. For substructures we have a card index separated into various headings, such as mass concrete, stone masonry and reinforced concrete. These cards are filed according to overall heights of wall under each heading. By referring to this index, if we know the overall height of an abutment and length of wing walls, it is possible to estimate within two per cent of the exact quantities required for any substructure which we may design.

Some state departments have taken the trouble to plot curves showing quantities for various types of substructures. I cannot believe that such curves have any particular merit other than to cast a scientific glamour about the problem in question. Substructure conditions differ materially and the most satisfactory way of estimating is to turn to the card index and refer to a similar proposition where exact quantities are known.

Reference Books. A large number of reference books is a most valuable asset to a bridge office. Our office has secured most of the books which contain a good treatment of highway bridges. There is not at the present time a first-class treatment of highway bridges available. Some of the subjects which need further treatment are:

1. Road roller distribution on concrete floors. Tests should be performed somewhat in accordance with actual conditions usually encountered. The recent tests of the United States Department of Public Roads and other experiments by testing laboratories are not typical of conditions under a moving road roller on a country highway.

2. Wearing surfaces for concrete floors should be treated from a practical and ecomomic standpoint.

3. Sympathetic vibration in steel bridges and the effect of light and heavy floors in reducing this vibration.

4. Paint for steel bridges. The American Society for testing materials has assembled a mass of data on the subject

and a text book writer should be able to write one chapter on this subject and make recommendations for the ingredients of a few good paints.

5. Waterproofing for walls, arches and floors.

6. Specifications for creosote wood block floors. Most all books give a specification for steel bridges but the subject of floors has escaped most writers.

CONSTRUCTION.

Construction work should begin as early in the spring as weather and stream conditions will permit. Where work is done by contract, the contracts should be let early, preferably in January or February and not later than April or May, if in any way possible. Considerably lower prices can be secured in the winter or spring than is possible in the summer. If construction is to be done by day labor it is equally important that early arrangements be made for the delivery of material. Practically all kinds of hauling can be done more cheaply in the winter. Some materials, such as steel, often require considerable time for delivery and the only way of avoiding these troublesome delays is to get a good early start.

Under our present law, this can easily be done. All money for state aid work must be voted on or before September first of the year previous and most of it is voted at town meetings in April. This makes it possible to get a survey of the site made during the summer, the plans are gotten out in the fall and the supervisors are in position to take bids on the work during the winter.

Shops are always short of work during the winter months and will bid off steel bridges at almost cost in order to keep their men working. At the present time contracts for small jobs involving only 30 to 40 tons of steel can be let at the ridiculously low figure of $48 per ton erected. Contracts involving 300 to 400 tons of steel can be let as low as $46 per ton. These prices of course are not typical of all seasons of the year and later in the summer it is very probable that prices will advance to $65 per ton.

Where work is built by contract we try to let all the work in a county on a single day. Where bids can be taken on several jobs at one time, more and better bidders can be secured. These lettings are preferably held at the Court House and advertised through circular letters to contractors mailed out by the Highway Commission.

An earnest attempt is made to secure the cooperation and approval of all the officials interested before a contract is let. The chief engineer of the commission has frequently made the statement that if a piece of construction was carried out in any community which left an unfavorable sentiment in that community, the work was a failure even though, from an engineering standpoint, it might be of faultless design and construction. The policy of the Bridge Engineer has been to delay construction rather than proceed in the face of local disapproval.

In this connection it will be interesting to note that a proper explanation will often convert local sentiment. I recall my first trip with the Bridge Engineer shortly after beginning my work with the Highway Commission. An inspection of a bridge site was made to secure measurements for planning a new structure and to meet the local authorities and find out the local sentiment toward the improvement.

The Bridge Engineer had decided on a through concrete girder construction but before making a final recommendation asked the town board for an expression of their opinion in the matter. In this particular case a contractor had gotten hold of the town board first and had convinced them that a plate girder span was the only feasible construction to use. The comparative merits of the two types of structures were explained to the board and before leaving the Bridge Engineer told the board that it was his understanding that they wanted plans prepared on the basis of a concrete structure. The entire local board nodded their heads in assent and the concrete structure was used. This is only typical of hundreds of cases where permanent ornate structures have been built on the designs of the Commission in place of some cheap, unsightly design of a contractor. Waddell has well said in his de Pontibus that some bridge builders would be unable to perfect a good design even though they be given all the material and money necessary, this being due to their pernicious habit of skinning a structure to the minimum.

Our specifications provide that each contract shall be secured by a bond, to be filed within twenty days of the date of the contract. In most cases this is unnecessary but in a few cases it has been needed and badly needed. A surety bond is required for sums over $1000 at the option of the supervisors.

On the inside cover sheet of our specifications is provided a suitable bond form. The standard forms of the surety companies contain so many exceptions as to be practically worthless. And we avoid these forms absolutely.

To quote another provision of the specifications regarding completion, they provide that the contractor shall begin work a reasonable length of time in advance of the date of completion. If the work is unnecessarily delayed, and the contractor or his bondsmen do not put a good force on the job within ten days of the time he is notified to do so, he can be ordered off the job and the work completed by whatever means may be deemed most advisable, any extra cost being charged against his bond.

In interpreting these specifications it is not the intention and should not be for any engineer to resort to undue harshness but some contractors are very dilatory and some means to produce action is absolutely essential.

In the few cases where the bondsmen have been called upon, it has proven very satisfactory and effective.

Under our present organization we are not able to keep an inspector on any but the larger jobs, In order that all work may be completed in accordance with the plans and specifications we endeavor to get an engineer on the job just as the work is being completed, preferably before the construction force has left. It usually happens that there are a number of minor details which a contractor will have a tendency to slight. These are called to his attention before his men leave so there will be no possible excuse for not finishing the work in a proper way. Of course he can be made to come back to finish everything in accordance with the specifications but this is always a wearisome proposition and it is most satisfactory when these final instructions can be given while the men are still on the ground.

This is the proper place to discuss extras and deductions, if any are claimed for they can be investigated on the ground and a decision as to the validity of the claim determined then and there.

SUPERVISION DURING CONSTRUCTION.

Bridge work is badly in need of supervision during construction. In highway work where the contracts are small a good bridge builder cannot always be secured and very often it is necessary to let local men attempt the construction. In such cases an inspector is necessary to interpret the plans and quite often has to act as foreman on the job. The majority of these men are honest in purpose but very ignorant about bridge work and a good inspector is the only way of securing a first class job.

I remember one contractor who attempted to drive wood piles with a crudely devised driver. He was laboring under considerable difficulty and could not get the piles down to the proper penetration. He telephoned our office advising that he had encountered solid rock at a depth of ten feet. Our knowledge of this locality did not bear out this statement so an engineer was sent down to examine the foundations. The contractor had twenty feet leads erected and a 1000 pound hammer and was attempting to drive sixteen feet piles. in sand. The tops of several piles were badly twisted over and battered on top. The contractor drove a pile to demonstrate that rock could be found at a depth of ten feet. He failed to keep the pile straight in the leads and at about this depth the penetration ceased. He was then instructed to drive a pile and keep it straight in the leads. The pile dropped in the full sixteen feet and the contractor was amazed to find that foundations were nothing but sand for an indefinite depth. The leads were then extended to thirty feet and no more trouble was experienced. This case is only one of a thousand where an inspector on the work would have to act as foreman as well as inspector.

Disputes frequently arise between the supervisors and the contractor. If a good inspector is on the work this is avoided but in other cases it is necessary for an engineer to investigate the claims and decide as to their merit. I recall one particular case where the supervisors were quite unfriendly to the contractor and were trying to require him to excavate an unreasonable depth through deep water and almost solid rock. An engineer was sent to examine the foundations and ordered the excavation stopped. This is only one of many cases where the engineer's decision was advantageous to the contractor but in no way detrimental to the work.

The better class of contractors are very glad to have a good engineer or inspector on the work because they know the specifications will be justly interpreted. The dishonest contractor needs the inspection for the protection of the supervisors.

On a job not under our supervision, a contractor sold a riveted truss span to a town board. When the time to erect the structure came, he shipped in a second hand truss and erected it complete. One of our engineers happened to be in this vicinity and noticed the substitution. The contractor was immediately notified and without excuse or apology he served notice that he would ship in and erect a new span complete. This is a typical illustration of the wholesome effect of only a slight amount of supervision.

## RAPID ESTIMATING.

Rapid estimating is largely a matter of experience and judgment. Where discretion is used this can be reduced to a linear foot basis but of course this is only a rough method of getting at the cost of a structure. In 1913 the average cost of a bridge under ordinary conditions was $40 per foot of span for any type of structure. In 1914 this cost was reduced to $35 per foot of span and in 1915 the work has been going at about $30. However it is too early in the year to give this figure as an average because so many contractors are short of work at this time that they are taking contracts at cost solely for the reason of keeping their organization together.

In 1914 the average cost of bridges on a unit basis was as follows:- For I-beam spans, $8 per cubic yard for concrete in place and 3 cents per pound for steel erected. For plate girder spans and trusses, 3¼ cents per pound; for steel erected and $7.25 per cubic yard for concrete in place. For reinforced concrete bridges, flat slabs through and deck girders, $8.75 per cubic yard for concrete in place and 3 cents per pound for steel in place.

The reason the yardage price for concrete was lower on plate girder or truss bridges than for I-beam spans was because the individual jobs were very much larger. An I-beam job will average about 75 cubic yards of concrete while a truss or plate girder job will average about 140 cubic yards.

A good sized job will always bring out more and better bidders and a lower contract price is secured than is possible on a small job. Sometimes local men will take the small jobs but as a rule, all work is let to some of the established bridge companies.

To estimate on another basis, we have had sufficient experience in estimating to guess within 10 cubic yards of the amount of concrete in a special job. For heavily reinforced work the steel will average .03 tons per cubic yard. Quantities can be run up rapidly in this way and knowing the approximate unit prices an estimate can be made in a few minutes. As a check the $35 per foot of span will probably disclose any large error in the estimate. An accurate method of estimating has already been described under office practice.

FAILURES.

It is interesting to study failures as well as successes. A prominent engineer writing in Engineering News recently criticised the engineering press for publishing so much about successful construction instead of failures; his contention being that more can be learned by studying a structure which has failed than to read a glowing description of a successful project.

The chances which contractors sometimes take with improperly built forms is well illustrated by referring to a concrete girder structure built on our plans in 1913. The bridge consisted of through girders; two spans, forty feet length, twenty feet roadway. The forms were supported on large timbers resting on the bank at one end and large stone at the other end. When about through pouring the structure, a slight movement occurred in the supporting timbers due to the enormous dead load and the entire structure collapsed. This was a heavy loss to the contractor and caused a delay of several weeks in completing the structure. The contractors had been warned repeatedly regarding the instability of the false work but they preferred to take this chance and suffered a heavy loss as a result.

In one case a traction engine drawing a load of portable barns was crossing an old 80 feet pony truss, 14 feet roadway. The load was too wide to clear the trusses and the trusses were pried apart about four inches and the engine started. The only knee braces which the upper chord had were small plates riveted to the top of the floorbeams with two rivets. The prying apart of the trusses and the impact from the engine was sufficient to rip the heads off the rivets. Both trusses turned outward and the whole equipment dropped in the river. One man was killed and two injured.

During a period of high water last summer, one end of a pier supporting two stone arches was undermined and settled about one inch. This permitted the dislodgement of the key stone and a part of the arches dropped in the river. The water cut a hole vertically downward to a depth of eight feet at the upstream nose of the pier. Fortunately the abutments and one half the pier was in no way injured. The concrete foundation which had settled was blasted out and removed. The pier was carried down to a sufficient depth and the face well riprapped with stone. The arches were relaid and the bridge put in good condition at reasonable cost. Since only half of the roadway was impassible traffic across the bridge was never stopped or in any way inconvenienced.

PATENTS.

Perhaps no greater obstacle will be encountered by designing engineers than the innumeral patents which have been granted by the United States Patent Office. These patents cover every phase of designing but the most objectionable ones are the Bone patents on retaining walls, the Luten patents on reinforced concrete construction and the Thatcher patents on Arches.

The above mentioned patents cover every possible arrangement of bars in reinforced concrete construction whether of flat slab, girder or arch construction. It would seem useless to attempt to avoid these patents but it behooves engineers to keep well enough informed on the subject so that when litigation ensues the engineer will be able to invalidate these patents and get them set aside on the ground of prior use rather than to defend a suit on the claim of non-infringement.

The defense of the patent office in granting these patents is perhaps just. Their contention is that congress has so hampered their efficiency through limited appropriations that it is impossible to maintain an adequate library and a sufficient number of employees to make a thorough investigation into the merits of every patent. The result of this inefficiency is endless litigation.

One noticeable feature in connection with recent law suits is the tendency of litigators to concentrate their attention on small contractors who will find it cheaper to pay a royalty and sign a consent decree than to fight the case. In the majority of patent cases a favorable decision has been received in the lower court only or a consent decree has been granted.

Based upon investigations conducted by this office during the past year, it is very probable that all objectionable patents can be antedated. To mention a few specific cases, the patent of Mr. Luten's based on paving the stream bed of an arch span and tying the abutments together by reinforcing rods was published in a German paper years before Mr. Luten made application for a patent. This same publication contains a description of an arch showing reinforcement used substantially in the same manner as the Thatcher patent.

One defandant in a recent patent case advised me that a settlement could have been made for the small sum of $200 and full permission given to build work without further royalties. The only requisite in this case was to sign a consent decree. The court charges on this case have already reached $1200 and may r each #300 more before a decision is rendered.

Through the efforts of Mr. Gearhart of Kansas, Senator Bristow was induced to introduce a resolution in the Senate authorizing the committee on patents to investigate the Luten Patents. No doubt the majority of his patents will be set aside if this committee can make a thorough investigation.

A bill has just been introduced before the Wisconsin Legislature authorizing the attorney general to defend any patent infringement case when directed to do so by the Governor. This bill carries an appropriation so that any patentee who considers his patents infringed will be assured of plenty of litigation if this bill becomes a law. It is a simple matter to bluff the small individual into settlement but when the State Treasury is back of a movement it has sufficient influence to stop minor suits and has a very wholesome influence on the unprincipled patentee. It is reported that a cèrtain engineer's legal staff is considerably larger than his engineering staff. If this be true the engineering profession is certainly in need of investigation and unprincipled individuals barred from practice.

## LEGISLATION.

The organization of a highway department on such a basis that its effectiveness will not be destroyed or tampered with by each change in administration should be the aim of organizers of such departments. To explain how this can best be done is the purpose in writing this chapter.

The public is not educated to such an extent as to properly appreciate the value or necessity of engineering advice or supervision on highway construction. The idea is prevalent in the rural districts that anyone can build a road and that any contractor is competent to give advice on bridge construction. Some prominent attorneys have even made statements that they were competent to supervise road building.

To bring before the minds of the people, the importance of engineering supervision on highway work a wide campaign of publicity should be waged. Every great movement promulgated during the past decade has met with bitter opposition, but, if the cause was right, it has eventually been successful. There is no reason why highway improvement cannot be effected by waging a state wide campaign of publicity. The public should be instructed in the various types of construction in common use, not with the idea of dispensing with engineering advice but for the purpose of arousing interest in new and modern methods of construction and in reality create a demand for engineering advice

Probably the best way of arousing interest is through the local papers. A busy man will often throw a pamphlet in the stove without reading but an article in the daily paper is sure to be read and considered. Photographs of work before improvement and after improvement enhance the value of a construction article considerably. Drawings of construction work with a comprehensive description of the design will often be studied with deep interest. Articles describing engineering work must be of a mon-technical nature so that the farmer, the lawyer and the preacher can all understand the nature of the improvement.

The automobile industry is doing as much toward the advancement of the good roads movement as the engineering profession. There is nothing which will convince a man of the need of road improvement as quick as getting his car stuck in the mud. Practically all farmers are getting automobiles now and some legislation along this line must be considered because the automobile and the narrow tire are the two most destructive agents on a surfaced road.

The ideal system for a highway department would be to make the county the unit for construction with a competent county engineer in charge and a state department to act in an advisory capacity with authority to recommend types of construction and assist in the appointment of the county engineers.

The state department should consist of the head of the department of civil engineering at the state University; the state geologist and three successful business men to be appointed by the Governor with the consent of the senate. These members should not receive any compensation for their services because a higher class of men can be secured in this way than is possible on the limited salaries which political positions pay.

This commission should have authority to appoint a chief engineer and such assistants as are necessary for the proper carrying out of the work. The minimum requirements for chief engineer should be a C. E. degree from a state University, associate membership in the American Society of Civil Engineers, five years experience in highway construction and three years in responsible charge of work. The engineer complying with these requirements should receive atleast $8000 per annum. The educational requirements for county engineer should be the same as for chief engineer except that the membership in the American Society of Civil Engineers should be waived and the actual experience required could be reduced two years. The county engineer should receive no less than $3000 per annum.

The general requirements for these positions should be embodied in the statutes in order that competent men be secured. The salaries recommended may appear higher than is customary in highway work, Let us figure a little on what the engineer can do . Supposing a county has $300,000. for construction work in a single year. An expert in highway work can, on the most conservative estimate, save one per cent over what can be done by an ordinary engineer. This saving amounts to $3000. or the county engineer's salary saved in a single year. The actual saving through efficient handling of construction and the exercise of good judgment will more probably be from ten to thirty percent.

The reason for making the county the unit for administration is to relieve the state department of any blame which may result through faulty construction and thus prevent any general agitation against the administration when in reality the trouble is local and should be treated as a local matter. Much of the criticism of the state department in Wisconsin is due to the fact that all responsibility is carried by the state. If a method was perfected to transfer this responsibility to the county it would be a big advantage toward securing the harmonious support of all interests.

State aid seems to be desirable and necessary to serve as a stimulus for local units to vote money for road improvement. The majority of people look upon state aid as a gift and forget that state taxes come from the people the same as other taxes. The individuals who do investigate the matter and find that they lose by not voting enough money to secure their proportionate share are all the more enthusiastic about voting funds. The ultimate result of state aid is to expedite construction and create a favorable sentiment toward road building.

Of the thirty-six states which now maintain state highway departments, thirty-four have state aid roads. This shows that state aid is a popular method for bringing about road construction.

The improvement of all roads should be under the direction of the county engineer and the state commission but only the trunk line roads should receive state aid. The method of laying out trunk line roads is a matter which would have to be determined in every state and no general rules would be of value.

The automobile license should be placed on a graduated horsepower basis and the proceeds turned into the state treasury as a maintenance fund for state aid roads or for other road purposes as may seem advisable.

I have not distinguished between roads in bridges in discussing the matter of legislation because both are necessary in the construction of a highway and the bridge is of but little service without a good road leading to it.

Success in highway building can only be secured through the cooperation of the local authorities and the state authorities.

The best way of avoiding unfavorable legislation is to create a spirit of enthusiasm toward highway improvement through a systematized plan of cooperation which will result in successful and economical road and bridge construction.