FINAL REPORT
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HISTORY OF EARLY BRIDGE SPECIFICATIONS: A REPRINT OF A PAPER BY J. N. CLARY

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Abstract

This report is a reprint of an informed review of the specifications for iron and steel bridges, both railroad and highway structures, dating from the mid-19th through the early 20th centuries. It is reprinted with only minor editing as a companion to an earlier report, *Best Practices for the Rehabilitation and Moving of Historic Metal Truss Bridges*, VTRC 06-R31.

The document was discovered in the files of VDOT's Structure & Bridge Division during research for the earlier study. The folder containing the paper ascribed its authorship to Mr. J. N. Clary, State Bridge Engineer from 1952 to 1972 and Chair of the Transportation Research Board's Structures Section from 1962 to 1969.

It is a document that reflects the thinking and practice of the bridge engineering practice of the late 19th and first part of the 20th centuries and the gradual evolution of specifications for metal bridges during that period. It is believed that the document will be of interest to cultural resource personnel and bridge engineers interested in historic metal bridges.

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Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation, the Commonwealth Transportation Board, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ABSTRACT

This report is a reprint of an informed review of the specifications for iron and steel bridges, both railroad and highway structures, dating from the mid-19th through the early 20th centuries. It is reprinted with only minor editing as a companion to an earlier report, *Best Practices for the Rehabilitation and Moving of Historic Metal Truss Bridges*, VTRC 06-R31.

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FOREWORD

This document was found in the files of the Virginia Department of Transportation's (VDOT) Structure & Bridge Division in 2005 during the research associated with a project (*Determination of Best Practices for the Rehabilitation and Moving of Historic Metal Truss Bridges*, VTRC 06-R31) conducted by the Virginia Transportation Research Council (VTRC) and VDOT's Knowledge Management Division. It is a typed manuscript on 8.5-inch by 11-inch paper reproduced in what appears to be an early photostatic process. It is in a modern ACCUPRESS binder, with the title "History of Early Bridge Specifications" typed on an adhesive label that is attached to the front cover.

There is no cover sheet, date, or author's name attached to the document. A second copy subsequently located in the VDOT Research Library is labeled under the same title and is also undated, but its cover credits J. N. Clary, State Bridge Engineer from 1952 to 1972, as the author. Mr. Clary also was involved in the technical activities of the Transportation Research Board through its bridge committees, serving from 1962 to 1969 as Chair of the Structures Section.

The first few paragraphs of the document note that the material "indicates some of which has been accomplished so far in an endeavor to study the development of design and fabrication specifications for iron and steel structures of the past." The majority of the references and citations cover the period 1871 through 1905; the latest reference is 1938. The manuscript contains references to photostatic copies, a technology developed in the late 1940s but not common until the 1950s and 1960s. For this reason, a tentative date of the early 1950s or later was assigned to the document (i.e., after photostatic copies were readily available). The majority of the resources cited were in the University of Illinois library, with some at Ohio State University. A search of research sources and library holdings did not uncover any published version of the manuscript.

The purpose of the document is unknown, although it might have been a study project or proposed article by Mr. Clary or a document by others that he discovered and saved. Regardless of its authorship, it is obvious that Mr. Clary recognized the value of an informed review of the evolution of metal bridge specifications during the latter half of the 19th century and the early years of the 20th.

Given the material's value for modern engineers and preservationists grappling with issues regarding historic metal truss bridges, we decided to transcribe and publish the Clary document in order to make it more widely available. With the exception of a few corrections of arguably misspelled or misaligned text and some minor reformatting of fractions and formulas for clarity, the document is an exact transcription of the original. The original pagination was retained and is placed at the upper right corner of each page.

The document reflects the thinking and practice of the bridge engineering community of the late 19th and first part of the 20th centuries; this is particularly noticeable in the use of some now-outmoded terminology (such as the interchangeable use of "stress" and "strain") and the methods of presenting some formulae. Such period terms and methodology do not, however, detract from the overall value of this document in bringing together an extensive amount of information on early metal bridge specifications.

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Ann B. Miller
Virginia Transportation Research Council
Charlottesville, Virginia, October 2006

History of Early Bridge Specifications

J. N. Clary

The material that follows indicates some of what has been accomplished so far in an endeavor to study the development of design and fabrication specifications for iron and steel structures of the past.

The ultimate aim of this work is to follow the specifications from their beginning to the present, indicating the person responsible for and the reason behind each change, addition, or omission. The author believes that the best manner in which this can be accomplished is by the consideration of each clause separately.

The success of this endeavor depends upon the information that is available. A preliminary search was made during the last year for the important specifications before 1905. The specifications and information that were obtained from the various sources contacted are listed in the bibliography (Part B). The amount revealed was sufficient to warrant the continuation of the work. The bibliography does not cover the period 1871 to 1905 thoroughly, and since the search was primarily for specifications dated before 1905, the bibliography is especially deficient in specifications since 1905. The earliest specification discovered, that was applied to structures generally, was dated 1871.

Additional material or information pertinent to this study is earnestly desired. The bibliography contains for the most part all the information that is available to the author at the present time. Any additional specifications or information concerning specifications, authors of specifications, specific clauses, or early design rules that were in common usage before the publication of specifications will be greatly appreciated. It is the author's conviction that the origin of the clauses in specifications can be found in the rules governing designing that the engineers used; and that in most cases, clauses were incorporated in specifications after their stipulations had been used in practice. One of the main purposes of this study is to discover the basis for including these clauses in specifications.

The discussion in Part A covers only some of the important specifications that were available. The companies whose specifications have been abstracted were some of the earlier ones that had issued specifications at intervals which would permit a comparison of the changes and additions that took place. Because of the need of brevity only a few companies were selected, and the author does not contend that the specifications included in the discussion are the most important.

The discussion summarizes the items of greatest interest to the author for the specifications mentioned. It has been included to show the content of the specifications at various dates by the different companies.

In the bibliography, the author of each specification has been indicated if his identity was known; however, the authors of some were unknown.

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PART A

Chapter I

Introduction

1. Foreword.--There have been many histories written which pertain to structures of iron and steel; however, the information concerning design specifications has been much more limited. A committee of the American Railway Engineering and Maintenance of Way Association* wrote an "Historical Sketch of the Development of American Bridge Specifications" in 1905. This is the best article known to the writer on the development of design specifications in use before 1905 that dealt with iron and steel.

A few brief bibliographies that list specifications for short periods can be found, but the writer has been unable to discover an extensive one or one that extends over a long span of years.

The task undertaken has been that of collecting such material as was available, compiling a bibliography, and comparing the more important specifications. Because of the magnitude of the project, it has been necessary to limit the period covered to that prior to 1905.

Some specifications later then 1905 that were at hand or easily obtained are included in the bibliography, but the list is by no means complete.

2. Acknowledgements.--The material studied and included in the bibliography has been obtained from various sources. Because the sources are of the utmost importance, they have been indicated in each case in the bibliography. The records and information made

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*No 171. (A reference given in this manner indicates the number of the item in the bibliography.)

available by, and the gifts from the many people who have contributed have been of very great consequence in this work. Much of the early material found was of such great importance (in several cases being in the personal handwriting of distinguished pioneers in American bridge engineering) that it seemed imperative to provide a permanent record in the form of filmed copy or carefully typed reproductions.

Chapter II

Specifications Before 1871

1. Specific Specifications.--For some time before 1871, specifications for iron bridges had been written. These specifications each covered a specific bridge, in some cases, of many spans and in others only one. They included many regulations for the fabrication and quality of the material, and pertained very little to design. The bridges had definite lengths, and were to be used for predetermined purposes; however, some of these specifications were quite complete, and with only a few minor changes or additions, could have been used as general specifications. Certain limitations governed the design and fabrication of every bridge constructed, and if a set of specifications was written for a bridge, it applied to that one only. For another bridge, this set of specifications would have to be revised; therefore, the existence of general specifications was brought about because of the need for uniformity, and the resultant economy, both for the purchaser and the contractor.

An article in Volume VI of the Proceedings of the American Railway Engineering and Maintenance of Way Association* entitled "Historical Sketch of the Development of American Railway Bridges," refers briefly to the men who were influential in the construction of iron bridges just before 1871, and the work they did.

2. The First General Specification.--On March 1, 1871, there was issued a general specification, entitled, "Specifications for Iron Railway Bridges and Viaducts"** as constructed by Clarke, Reeves

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* No. 171.
** No. 2.

and Company of the Phoenixville Bridge Works, Phoenixville, Pennsylvania. The Clarke, Reeves and Company later became the Phoenix Bridge Company. The writer has been unable to find any general specification of earlier date than this, and believes it to be the first, which agrees with the report of a committee of the American Railway Engineering and Maintenance of Way Association* according to the material given in the article previously mentioned.

Information concerning the existence of early specifications, and their correct dates and authors, has been obtained by correspondence with consulting engineers; engineers of railroad companies, steel companies, state highway departments, and federal bureaus; professors of civil engineering in universities; and retired engineers; as well as various libraries. Most of the material given in the bibliography was based upon the information derived from these sources.

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* No. 171.

Chapter III

General Design Specifications

1. The Phoenix Bridge Company.--The dates of the specifications for the Phoenix Bridge Company that are listed in the bibliography include 1871 (as Clarke, Reeves and Company), 1885, 1887, 1888, and 1895. The specifications dated 1887 and those dated 1888 are the same. In 1887, they were issued separately as specifications*, and in 1888, they were included in The Album of Designs of The Phoenix Bridge Company**.

(a) 1871.--"Specifications for Iron Railway Bridges and Viaducts,"*** had requirements for loadings, allowable strains****, quality of material, and workmanship. Because this was the earliest of all the general specifications, it will be given verbatim, except for the portion which deals with the directions for the purchaser.

> 1. These structures are proportioned to sustain the passage of the heaviest cars and engines in use, for coal, freight or passenger traffic, at a speed of not less than thirty miles per hour, viz., two locomotives coupled weighing thirty tons on drivers, in space of twelve feet; total weight of engine and tender, loaded, sixty-five tons each, and followed by the heaviest cars in use, viz.: loaded coal cars, weighing twenty tons each, in twenty-two feet. The iron-work will be so proportioned that the above loads, in addition to the weights of the structures themselves, shall not strain the iron over 10,000 pounds per square inch tensile, or 7,500 pounds per square inch shearing strain, and reducing the strain in compression in proportion to the ratio of length to diameter, by Gordon's formula.
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> 2. The iron used under tensile strains shall be of

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* No. 44.
** No. 49.
*** No. 2.
**** In the older specifications, the words stress and strain had the same meaning.

tough and ductile quality, and be capable of sustaining the following tests:

ROUND BAR — 1 1/2 inches diameter by 12 inches long.
Ultimate strength.....55,000 to 60,000 #/sq. in.
No permanent set under 25,000 to 30 000 #/sq. in.
Reduction of area at breaking point, average. . 25 per cent
Elongation. . . . . 15 per cent

Cold bend, without signs of fracture, from 90 to 180 degrees.

3. All workmanship shall be first-class. In work having pin connections, all abutting joints shall be planed or turned, and no bars of wrought-iron having an error of over 1-64th of an inch in length between pin-holes, or over 1-100th of diameter of pin or hole, shall be allowed. In riveted work, all plates and joint plates shall be square and truly dressed, so as to form close joints. Rivet holes shall be spaced accurately and truly opposite. Rivets shall be of the beat quality of rivet iron, shall completely fill the holes, and shall have full heads.

Chord-links, main ties, and suspension bolts, shall be die-forged without welds. Screw-bars shall have threads enlarged beyond diameter of bar, and shall be fitted with radial nuts and washers.

All bars subject to tensile strains may be tested to 20,000 lb. per square inch, and struck a smart blow with a hammer while under tension; and if any show signs of imperfection, they shall be rejected.

All the iron-work shall be painted, before leaving the Works, with one coat of metallic paint and oil. All machine-cut work shall be covered with white lead and tallow before leaving the Works.

4. These bridges shall not deflect under the passage of a train of locomotives moving at thirty miles per hour over 1-1200th of their length, and shall return to their original camber after the passage of the train.

(b) l885.--"General Specifications for Railway Bridges,"* taken from The Album of Designs of the Phoenix Bridge Company was for iron, and pertained to steel only in the allowable bending

* No. 29.

stress on extreme fibers of steel pins, given as 20,000 p.s.i., as compared to 15,000 p.s.i. for wrought iron.

The floor load was 400 pounds per foot for ties, guard timbers, rails, spikes, etc. and a moving load of two engines followed by a train weighing 3000 pounds per lineal foot. The engines had a gross weight of 85 1/2 tons each, 24,000 pounds per axle on the drivers and 15,000 pounds per axle on the tender. This moving load is the same as Cooper used, in his 1884* specifications under Class A.

The wind pressure was 150 pounds per lineal foot for the unloaded chord and 450 for the loaded chord, 300 of which was considered as moving load. The pressure on trestle towers and viaducts was 50 pounds per square foot of surface area for unloaded structure, or 30 for the surface area of structure and train.

The greatest allowable stresses were: for tension in eye-bars 10,000 p.s.i., and for tension in lower chords of lattice girders and lower flanges of plate girders, and for compression in plate girder flanges--8,000 p.s.i. Tension members other than lower chords had allowable values ranging from 7,000 to 15,000. Compression in columns was given by 6 modifications of the Rankine-Gordon formula depending on the end bearing and form of column. For a latticed or common column with flat ends, the value $P \equiv \frac{7800}{\left(1 + \frac{L^2}{40{,}000\, r^2}\right)}$ ** was used. When the length exceeded

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* No. 23.

** In reduction formulas for compression members, P will be used as the allowable strain in p.s.i., L as the length in inches, and r as the least radius of gyration in inches.

120 radii of gyration, the formula for pin-end angle-struts governed, in which

$$P = \frac{7800}{\left(1 + \frac{L^2}{16,000\, r^2}\right)}.$$

Members sustaining alternate tension and compression were designed to carry the largest stress added to 6/10 of the smallest.

For rivets and pins, the greatest allowable shearing stress was 7,500 p.s.i. and the stress in bearing was limited to 12,000 p.s.i.

Wrought iron was required to possess a minimum limit of elasticity of 26,000 p.s.i. The ultimate strength for specimen taken from bars had to be at least 48,000 to 50,000 p.s.i., depending on the size of the bar. The elongation had to be not less than 18 per cent in 10 inches. The ultimate strength and elongation limits were reduced for specimen from plates and shapes, the lowest being 46,000 p.s.i. and 12 per cent respectively.

All iron used in tension had to bend cold 90 degrees without cracking, to a curvature whose radius was about the thickness of the material, and at least one-third had to bend 180 degrees. For plates and shapes, the radius was one and a half times the thickness.

Highway bridges were to be designed for a moving load, of 80 pounds per square foot of clear roadway and sidewalk for spans of less than 125 feet, or 60 if the span exceeded 125 feet. In all cases, the floor system was designed to provide for a moving load of 100 pounds per square foot.

For highway structures, the allowable stresses were 20 per cent greater than for railway.

(c) 1887.--“Standard Specifications for Railway and Highway

Bridges and Viaducts"* applied equally to iron and steel. Values still used in 1887 but given the 1885 specification discussed above are not repeated below.

The compression members had their permissible working stresses computed by using 6 modifications of the Rankine-Gordon formula just as in 1885, but the constants in the formulas were changed. For a common column with flat ends the form used was $P = \frac{8000}{\left(1 + \frac{L^2}{40{,}000\,r^2}\right)}$. Stresses for angle struts with flat ends were figured from the formula P = 9,000 – 30 L/r, but lateral struts were allowed 140 per cent of these values.

For lower chords in spans over 150 feet in length, the permitted unit stress was taken as $8000\left(1 + 0.9 \times \frac{\text{Min. Total Stress}}{\text{Max. Total Stress}}\right)$ or at least 10,000.

For shear and bearing on pins and rivets, the allowable stresses were 7,500 and 12,000 p.s.i. respectively for live and dead loads, 10,000 and 17,000 respectively for wind stresses, and 9,000 and 15,000 respectively for combined wind stresses and live load. For field driven rivets, 20 per cent was deducted from these values. The bending stress permissible on pins was 15,000 p.s.i. for dead and live load, 20,000 for wind stresses, and 18,000 for wind stresses combined with live load.

All of the foregoing material applied to iron, and the following was for steel.

The tensile working stresses in members of spans less than 200 feet in length varied from 9,000 to 19,000 p.s.i., being 13,200

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* No. 44.

p.s.i. for main web and lower chord eyebars. For spans of over 200 feet, the working stress in lower chord members was the greater of either 13,200, or $10{,}000\left(1+\frac{\text{Min. Total Stress}}{\text{Max. Total Stress}}\right)$. The tensile or compressive stress allowed in flanges of girders was 10,000 p.s.i.

The working stresses in compression members were obtained by multiplying the values for iron compression members by 4/3, but for members in spans over 200 feet in length these values were additionally increased by the ratio used for the lower chords. The formula for angle struts with flat ends was P = 12,500 – 44 L/r. For lateral struts, 140 per cent of the values derived from this formula were used.

The maximum limits in p.s.i. for stresses in pins and rivets were: for sheer, 10,000 for live and dead loads, 13,000 for wind stresses, and 12,000 for combination of live load and wind stresses; and for bearing, 16,000 for live and dead loads, 22,000 for wind stresses, and 20,000 for live load combined with wind stresses. Field driven rivets were restricted to 80 per cent of these values. The bending stress for pins was not to exceed 20,000 p.s.i. for dead and live loads, 26,000 for wind stresses, or 24,000 for wind stresses combined with live load.

For iron, the ultimate strength requirement varied from 46,000 p.s.i. upward, depending on the size and intended use; but for shaped iron the value was derived from $50{,}000 - \left(\frac{7{,}000 \times \text{area}}{\text{circumference}}\right)$. The elastic limit was to be at least 1/2 the ultimate strength, but not less than 26,000 p.s.i.

For steel, the ultimate strength was not to be less than

62,500 p.s.i. for tension members, 68,000 for compression members, and 60,000 for rivets. Tension members and rivets were allowed a variation in their respective limits of 4,000 p.s.i.; but they were to have elastic limits at least equal to 1/2 their ultimate strengths, and percentage of elongation not less than $\frac{1{,}200{,}000}{\text{tensile strength}}$ in a length which for each member was 10 times its shortest dimension.

The clauses governing highway bridges were identical with those in the 1885 specification.

(d) 1895.--"Standard Specifications of The Phoenix Bridge Co. for Steel and Iron Railway and Highway Structures"* had many changes from the 1887 specifications, but only the most important ones will be discussed.

A heavier live load was suggested. It consisted of 2 engines, weighing 104 tons each and having 30,000 pounds on each of 4 driver axles, followed by a uniform bed of 3,500 pounds per lineal foot. This engine is the same as Cooper's Class Extra Heavy A in his 1890 specifications.**

The centrifugal force for structures on curves was taken as $W\left(\frac{112}{R}\right)$ in pounds, where W was the weight of the train in pounds and R was the radius of the curve in feet.

The greatest working stresses in p.s.i. for tension members composed of plates or shapes was $8{,}500\left(1+\frac{\text{Min. stress}}{\text{Max. Stress}}\right)$ for steel and $7{,}000\left(1+\frac{\text{Min. stress}}{\text{Max. stress}}\right)$ for iron.

For compression members the Rankine-Gordon formula was still used but the constants used were different than in 1887.

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* No. 81.
** No. 54.

The greatest pressure allowed on masonry was 300 p.s.i. In spans over 75 feet in length, friction rollers were used at one end. The rollers were not to be less than 2 1/2 inches in diameter, and the pressure (undoubtedly in pounds) per lineal inch of roller was 350 D for iron and 500 D for steel, D being the diameter of the roller in inches.

All members, except bracing, subjected to alternate stresses were designed for both stresses, increasing each by 8/10 of the smaller.

The clearance diagram indicated a 14 foot width and a 20 foot height.

The camber was to be at least 1/500 of the span.

Plate girders were used for spans up to 80 feet in length. One sixth of the web plate area was considered as part of the flange section. Compression flanges were permitted to have unsupported lengths not greater than 20 times their widths. Stiffeners were placed at bearing points and points of concentrated loading. If the shearing stress in the web exceeded $\frac{12{,}000}{\left(1+\frac{H^2}{3{,}000}\right)}$ stiffeners were spaced at intervals about the depth of the girder.*

Lattice girders were preferred for spans of 80 to 125 feet, and pin-connected trusses for spans over 125 feet.

Angles in tension had to be connected by both legs.

The minimum pitch for rivets was 3 diameters, and the maximum pitch was 6 inches or 16 times the thickness of the thinnest

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***** H was the ratio of depth of web to thickness.

outside plate.

For compression members, the maximum unsupported width was 32 times the thickness of the member, except for cover plates which were allowed unsupported widths of 40 times their thicknesses.

All rivet holes in steel over 5/8 inches thick had to be punched 1/8 inch smaller than final size end reamed to full dimension.

The yield point for steel was 33,000 p.s.i., except for rivet steel and eyebars. Punched holes at 2 diameters from a sheared edge had to stand drifting to a diameter 50 per cent greater in each case than the original diameter, without cracking the metal.

The yield point for iron varied from 23,000 p.s.i. for plates over 43 inches wide to 26,000 p.s.i. for tension bars less than 5 square inches in area.

Loadings for highway bridges were given for city bridges, county bridges, and bridges carrying electric railways.

2. Work of George S. Morison.--Mr. George S. Morison was the author of many specifications. Some of these were for specific bridges, and others were entirely general in application. He was the author of the first printed specification for iron bridges for a particular railroad, namely, "Specifications for Iron Bridges,"* written for the Erie Railroad in 1873. Another specification was written by him in 1874** for the same company, but it was never printed. Mr. Morison's name was not attached to either of the copies studied nor was the 1873 copy dated; however, the 1874 copy was in handwriting which was recently identified as that of Mr. Morison's by Dr. O. E. Hovey who worked with him for many years.

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* No. 5.
** No. 6.
*** No. 171.

That the authorship and date of these specifications is correct is further substantiated by their agreement with material given in Volume VI* of the Proceedings of the American Railway Engineering and Maintenance of Way Association said to have been taken from specifications by this author and of these dates.

In addition to these, Mr. Morison wrote specifications which are still extant, dated 1883, 1885, 1886, and 1887, each of which applied to a particular bridge. Also included in this study are the "Bridge Standards" in use when Dr. O. E. Hovey had charge of Mr. Morison's engineering office in Chicago from 1890 to the end of 1895.

(a) 1873.--"Specifications for Iron Bridges,"** were prepared soon after Mr. Octave Chanute became Chief Engineer of the Erie Railroad.* They were printed and used to enable designers to submit bids that would be comparable.

The track weight was assumed to be 400 pounds lineal foot per track, not including the weight of iron in the structure. The moving load varied from 1,500 to 4,000 pounds for each lineal foot of truss, depending on the span and number of tracks and trusses. For a double-track through bridge with two trusses and a span of 50 feet, the load was 3,500 pounds per foot of truss.

Up to spans of 50 feet, boiler plate girders were generally used. The allowable stress in the lower rib was 10,000 p.s.i. on the net section, and for the upper rib 7,500 in compression. Three-quarter inch rivets were used with a 6 inch pitch. The thicknesses of the web plates varied from 1/4 to 1/2 inch, depending on the span and number of tracks and trusses. Tee iron, vertical stiffeners were used at least every ten feet or less.

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* No. 171.
** No. 5.

Truss bridges were required when the span exceeded 50 feet. Through trusses had a clear distance between them of 15 feet, and a head room of 19 feet above the rails.

Tensile members were to have an ultimate strength of 55,000 to 60,000 p.s.i., an elastic limit of 23,000 p.s.i., and an elongation of 10 per cent of their lengths. The allowable strain for tensile members was 10,000 p.s.i. All welds were tested to 20,000 p.s.i.

Maximum compression permitted was 8,000 p.s.i. when the least dimension was 1/12 or more of the length, and when less than 1/12, the compression allowed was determined by Gordon's formula with a factor of safety of 5.

The limiting shearing strain on pins was 6,000 p.s.i., and the diameter had to be not less than 2/3 of the largest dimension of any tension member attached. The effective length of the pin could not be greater than the breadth of the foot of the post plus 4 times the diameter of the pin. Strain in floor beam suspenders was not to be more than 8,000 p.s.i.

Laterals were used from 7/8 inch rounds to 1 1/2 inch rounds, depending on their location in the truss and on the span of the truss, and the lateral struts had equal strengths.

In single-track through bridges, two longitudinal iron floor beams were used, each proportioned to carry a moving load of 2,500 pounds per running foot. Three longitudinal floor beams were used in double-track through bridges, the outside longitudinal floor beams were designed for a rolling load of 2,500 and the inside beam for 4,500.

(b) 1874.-- "Specifications for Iron Bridges"* were used by an

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* No. 6.

office force, of which Mr. C. C. Schneider was chief draftsmen and designer, according to information in Volume VI* of the Proceedings of the American Railway Engineering and Maintenance of Way Association.

The moving load was changed slightly from that used in 1873. It was 5,000 pounds per foot of track for lengths of 20 feet or less and varied to 3,000 for lengths over 40 feet. Ten per cent was deducted for parts which were fully strained only by the load from two tracks. For spans longer than 125 feet, a load of 2,500 pounds per foot of track was assumed.

The clear head room above the rails was increased from 19 to 20. The ultimate strength for tensile members was reduced to a requirement of 50,000 p.s.i., the elastic limit was raised to 26,000 and the minimum elongation was changed to 15 per cent of their lengths.

Strain in all tensile members was limited to 10,000 p.s.i. and in members less than 5 feet in length to 7,000. For compression members, Gordon's formula was given in a modified form: $P = \frac{40{,}000}{\left(1 + \frac{L^2}{40{,}000\ r^2}\right)}$ with the same factor of safety of 5. For pin joints, 20 per cent was deducted from the strength as given by the formula. The maximum of 8,000 p.s.i. was retained for members whose least transverse dimensions were at least 1/12 of their lengths. The shearing strain was kept at 6,000 p.s.i. for pins.

Plate girders were proportioned on the supposition that all bending strains were resisted by the upper and lower ribs, and all the shearing strains by the web plates. Strain in upper chord was not to exceed 7,500 p.s.i.; nor in the lower chord,

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* No. 171.

10,000 p.s.i. on the net section. Sheer on web plates was not to be greater than 5,000 p.s.i. of section, and the plates were at least 1/4 inch thick. Stiffeners were spaced so that 20 square feet was the maximum area of plate without stiffeners.

Rivets were allowed a shearing strain of 6,000 p.s.i., and a crushing strain of 10,000 p.s.i. Butt joints were not relied upon in riveted work, and whether in tension or compression, were reinforced with cover plates of sufficient strength to meet the requirements of the strains. The clear distance between rivet holes, or between holes and the edge of iron in the line of the fiber, was not to be less than twice the diameter of the rivet.

The ultimate strength of boiler plate iron was to be not less than 45,000 p.s.i., and the elongation, 12 per cent of the length of the specimen.

Girders of quarter depth had to have a clear distance apart of 14 feet.

The maximum pressure on masonry was not to exceed 250 p.s.i. Bridges over 50 feet long had turned rollers of wrought iron running between surfaced cast iron plates at one end. The weight on these rollers was never greater than 500 pounds per lineal inch for each inch of diameter of roller.

Pin jointed structures were preferred for spans over 50 feet.

(c) 1883 to 1887.--"Specifications for Superstructure of Bridge Across the Willamette River at Portland, Oregon,"* were written by George S. Morison for the Northern Pacific Railroad, and dated May 15, 1883. The only portions that are within the scope of

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* No. 22.

this study are the articles on material and riveted work.

Sample test bars for compression steel were to bend 180 degrees around their own diameter without sign of crack or flaw. The elastic limit was to be not less than 50,000 p.s.i.; the ultimate strength not less then 80,000 p.s.i., and the elongation 15 per cent.

Sample bars for steel used in rivets and eye-bars had to bend flat upon themselves, have an elastic limit of not less than 40,000 pounds, an ultimate strength not less than 70,000 pounds, and an elongation of 18 per cent.

Small samples of the iron used in tension members had to show an elastic limit of 26,000 p.s.i., an ultimate strength of 50,000 pounds, and elongation of 15 per cent in a length of 8 inches. When the samples were taken from plates or shapes, the elastic limit could be as low as 24,000 pounds; the ultimate strength, 47,000 pounds; and the elongation, 10 per cent in a length of 8 inches, unless the plates were more than 30 inches wide, then 8 per cent.

The riveted steel work was not to have punched holes larger than 11/16 of an inch in diameter, and then each hole was reamed to 15/16. All rivets in steel members were to be of steel and of such size as to fill the hole before driving. Rivets were to be driven by power whenever possible.

"Specifications for Superstructure of New Union Pacific Bridge Across the Missouri River at Omaha, Nebraska,"* were written for the Union Pacific Railroad, and dated December 1, 1885. As far as the requirements governing materials and riveted work (which are the only parts of interest here), they were the same as

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* No. 30.

the preceding, except that steel used in compression members was regarded as High steel and that used in rivets and tension members as Low steel. “Specifications for Bridge Superstructure on Oregon Railway and Navigation Company’s Lines,”* dated May 1, 1886 and “Specifications for Superstructure for Bridge Across the Missouri River at Rule, Nebraska,”** dated July 20, 1886 are two more specifications by George S. Morison, having values covered for all practical purposes in the preceding discussion.

“Specifications for Superstructure of Ohio River Bridge at Cairo, Illinois”*** is dated March 23, 1887 and has George S. Morison and E. L. Corthell listed as the Engineers. It is brief, but only the paragraphs on materials and riveted work will be mentioned.

The sample bars of steel were required to show an elastic limit of 40,000 p.s.i., and ultimate strength between 67,000 and 75,000 p.s.i., and an elongation of at least 20 per cent in a length of 8 inches. In bending tests, a bar was to close back against itself, without cracks or flaws. Steel with an ultimate strength of 60,000 p.s.i. was accepted for rivets.

Rivet holes were drilled unless the contractor desired to punch holes 3/32 inch small and ream. All rivets were of steel and of such size that they filled the holes before driving.

(d) 1890.--“Bridge Standards”**** was not a specification, but a set of standards to be followed in a design office. The material was arranged in a manner similar to that in which it would appear in specifications, and was very complete. Comments and explanations were included with the rules and limitations for designing.

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* No. 34.
** No. 32.
*** No. 38.
**** No. 56.

3. Work of G. Bouscaren.--Mr. G. Bouscaren has been given credit for writing specifications for the Cincinnati Southern Railway published in 1875 in a report by T. D. Lovett.* The following statement appears in the report in which the specifications were found, "G. Bouscaren, First Assistant Engineer, 'Department of Construction,' has charge of all matters at the principal office in Cincinnati relating to the construction of the railway."**

During 1875, many tests were made on iron columns and also to determine the moduli of elasticity of iron specimens by the four bridge companies which had contracts to provide the material for bridges to be built for the Cincinnati Southern Railway. The results obtained can be found in "Report of Tests of Iron Columns and Struts used in Construction of Bridges, Trestles, and Viaducts of the Cincinnati Southern Railway."*** Concerning these tests and some others made by the Erie Railroad, this statement appears in the Proceedings of the American Railway Engineering and Maintenance of Way Association* in 1905. "These tests, with those made by the Erie in 1873, were near the fountain head of our present elaborate and extensive system of commercial testing of structural material."

A second Report on the Progress of Work and Cost of Completing and Maintaining the Cincinnati Southern Railway was published in 1880. It was written by G. Bouscaren and also includes a set of specifications.****

On April 1, 1881, the Cincinnati Southern Railway issued "Specifications for Bridge and Viaducts of Iron and Timber."*****

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* No. 171.
** No. 7.
*** No. 8.
**** No. 14.
***** No. 18.

The Engineering Societies Library received a copy of these specifications from Mr. G. Bouscaren, which helps to confirm the author's belief that they were written by him.

As a Consulting Engineer, G. Bouscaren wrote separate specifications for both highway and railway bridges in 1887, and revised those for railway bridges in 1890.

(a) 1875.- "Specifications for Bridge and Trestle-Work"* were written for bridges of iron, wood, or a combination of both, but only the material pertinent to iron will be discussed.

Those specifications required all through bridges to have clear width of 14 feet, and a height in the clear of 18 1/2 foot above the top of the rail. Iron trestle-work was to be built in spans of 20 feet or upward in length; supported by trestles in vertical sections of 30 foot and fractions of 30 feet, as each particular case required. The centers of the trestle posts were to be at least 10 foot apart at the top.

The rolling load was assumed to travel at least 30 miles per hour, and consisted of two locomotives, each weighing 66 tons, followed by loaded cars weighing 20 tons each in a space of 22 feet. The weight on drivers was 36 tons in a space of 12 feet, at 12 tons per axle. Because of impact, from 10 to 30 per cent of the above load was added in the calculation of floor beams, stringers, suspension lines, counter-rods, and all other parts subject to sudden strains in the passage of rolling loads. The maximum deflection of a bridge under the passage of a train was not to exceed 1/1200 of its length.

In addition to resisting live and dead load, trestles had to

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* No. 7.

have sufficient strength to resist a wind pressure of 13 pounds per square foot, when the trestles were covered with passenger cars. "In bridges vertical lateral rods and struts must be of sufficient strength to resist, in addition to the live and dead loads a pressure of wind equal to 50 pounds per square foot, unless otherwise specified."*

Maximum strains were given for the iron work when resisting the specified rolling load together with the weight of the structure including the floor, with 125 pounds per lineal yard added for rails, spikes, and joints. The limits were 10,000 p.s.i. in tension and 7,500 p.s.i. in shear. Compression strains were to be reduced by the Gordon formula with a factor of safety of 6. For members subjected to transverse strains, the maximum compression was not to exceed 8,000 p.s.i. Shear in pins was not allowed to exceed 7,500 p.s.i. and bearing was limited to 10,000 p.s.i.

The ultimate strength of iron used in tension was not to be less than 60,000 p.s.i.; and no permanent set to occur when the strain was 25,000 p.s.i. and the test bar was struck a smart blow with a hammer. The elongation was to be at least 15 per cent. (Test bars were 12 inches long). When cold, the iron was to bend from 90 to 180 degrees without sign of fracture.

Iron used in compression had to have an elastic limit of not less than 25,000 p.s.i.

All abutting joints were to be planed, and joints in riveted work were to be square and truly dressed. Rivets were required to completely fill the holes, and the area of rivets was not to be less than the sectional area of the joined pieces.

(b) 1880.-"Specifications for Bridge and Trestle-Work"** were

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* No. 7, p. 24.
** No. 14.

written for bridges of iron or wood, or a combination of both, just as were the 1875 specifications, and are similar to them. To minimize repetition, only the important differences will be taken up.

Additions to rolling load because of impact amounted to 50 per cent for suspension links and riveted connections of stringers and floor beams, and 25 per cent to all other parts liable to sudden strain.

The weight of rails, spikes, and joints was assumed 44 pounds per lineal foot.

The pressure of wind was assumed equal to 30 pounds per square foot on all members of each truss, and on a train surface averaging 10 square feet to the lineal foot of track.

The length of columns was not to exceed 48 diameters, and the strain in compression members was reduced according to 6 modifications of the Rankine-Gordon formula depending on the shape of the columns and the end bearing with a factor of safety in every case of 5. For a square post closed on all sides, or open and latticed on two opposite sides, with flat ends, the form was $R = \dfrac{38{,}600}{\left(1 + \dfrac{L^2}{38{,}600\, r^2}\right)}$.

The thickness of plates in columns tied to be at least 1/30 of the width of the plate between supports, with a minimum thickness of 1/4 inch if both sides were accessible for painting, and 1/2 inch when only one face was accessible.

The compression in p.s.i. in the compressed flanges of beams was limited to 1/5 of $\dfrac{40{,}000}{\left(1 + \dfrac{L^2}{5{,}000\, b^2}\right)}$ *

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* b = breadth of compressed flange in inches.

The shear in webs of girders was not to exceed 1/5 of $\frac{40{,}000}{\left(1+\frac{d^2}{3{,}000\ t^2}\right)}$* in p.s.i.

Tension was not allowed in a direction transverse to the fibers of iron; nor shearing strain, in a direction parallel to them.

The maximum bending strain on the extreme fibers of pins was 15,000 p.s.i. For members in compression, the greatest spacing of rivets was 16 times the plate thickness, and the sectional area of rivets in a distance of two diameters from the end had to be equal to the area of the member.

The permissible strains were increased 50 per cent when the effect of wind pressure was considered.

The pressure on masonry was to be not more than 25,000 pounds per square foot, and friction rollers were allowed a pressure per lineal inch not over 540,000 x d, where "d" was the diameter of the roller in inches.

The ultimate strength of iron for tension members was to be not less then 50,000 p.s.i., and the elastic limit not less than 25,000 p.s.i.

The camber of iron trusses was to be 1/1200 of the span and the camber line was to fit the arc of a circle within 1/4 inch at any point.

(c) 1881.- "Specifications for Bridge and Viaducts of Iron And Timber,"** used by the Cincinnati Southern Railway, are more complete than those in use before 1881. They are similar to the

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* d = distance in inches between flanges or stiffeners, measured on a line inclined at 45^{o}. t = thickness of web in inches.

** No. 18.

earlier ones, and only the more significant additions or changes will be noted.

All parts of the structure were to be designed for strains produced by the weight of the structure itself; the rolling load in any position, moving at a speed of 30 miles per hour or being stopped suddenly while traveling at that speed; the specified wind pressure; and the effect of a temperature variation of 150 degrees.

The rolling load consisted of two locomotives weighing 79 tons each, followed by a uniform load, of 2,000 pounds per lineal foot. The engines had 4 driver axles with a load of 22,000 pounds each, 4 tender axles at 14,000 pounds each, and one pilot axle at 14,000 pounds.

The addition to the rolling load to provide for the effect of impact was 50 per cent for floor beam hangers and connections to stringers and floor beams, and varied for the other parts of the bridge subject to impact forces, from 25 per cent to 10 per cent depending on the span.

The wind pressure was taken as the greater of the following: 30 pounds per square foot on the exposed surface of both trusses and a train surface of 10 square feet per lineal foot of track, or 50 pounds per square foot on the exposed surfaces of both trusses.

The strain in compression was reduced, by three variations of the Rankine-Gordon formula depending on the end bearings. For posts with square bearings, and for top flanges of built beams between stiffeners, the form R = 1/5 of

$$\frac{38{,}000}{\left(1+\dfrac{L^2}{36{,}000\,r^2}\right)}$$

was used. The constant before the "r^2" was 18,000 for posts with pin bearings, and 24,000 for posts having a square bearing on one end and a pin bearing on the other. The length of a compression member was not to exceed 45 diameters.

The allowable pressure on pins and rivets was 15,000 p.s.i., which was also the allowable bending strain on extreme fibers.

An addition of 25 per cent to all specified limits of strain was permitted for strains due to wind pressure.

The top and bottom flanges of beams resisted the greatest bending moment without the aid of the web, and the web resisted the shearing forces without considering the flanges.

The elastic limit requirement for wrought iron was 26,000 p.s.i., and the value for the ultimate strength varied as follows: 52,000 p.s.i. for bars, 50,000 for shapes, and 48,000 for plates, with corresponding elongations in a distance of 6 inches of 20, 15, and 10 per cent respectively.

(d) 1887.--"General Specifications for Railway Bridges and Viaducts of Iron and Steel"* was issued by G. Bouscaren under his own name. It included requirements for steel, which were not given in the specifications he wrote for the Cincinnati Southern Railway. Values which are present in this specification but listed under those already mentioned will not be repeated; however, the noteworthy differences will be presented briefly.

The clear height above the base of rail was required to be 20 feet, and the clear width on curves was to exceed 14 feet on each side by a value in feet equal to $0.15 \times$ d being the degree of curvature.

The bottom chord of each truss in a through bridge was designed to resist a 60,000 pound thrust applied to the bottom of the

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* No. 37.

end post when the span was unloaded.

When practicable, iron trestles and piers had a width of base sufficient to prevent overturning due to wind pressure; however, sufficient anchorage was provided to resist at least 1/2 the overturning moment of the wind.

The bending effect produced on every individual member by wind pressure and the member's weight was considered.

The rails, guard rails, spikes, and joints were assumed to weigh 100 pounds per lineal foot of track.

The live load consisted of a concentrated load of 30,000 pounds followed or preceded, or both, by a uniform load of 3,000 pounds per lineal foot. The uniform load was either continuous or discontinuous, according to whichever gave the largest strains.

The limits for strains in iron members in p.s.i. were as follows; for tension in rolled bars--10,000; for tension in plates and shapes--9,000; for compression where L/r ratio was less than 50--8,000; for shearing across fibers--7,500; and on pins, for tension or compression on extreme fibers, or for bearing--15,000. For compression members having lengths greater than 50 times their radii of gyration, the allowable strain was found by the use of modification of the Rankine-Gordon formula, the constants of which depended on the types of end bearing. For members with square bearings, the form used was $R = \frac{8{,}000}{\left(1 + \frac{L^2}{36{,}000\, r^2}\right)}$. $R = \frac{9{,}000}{\left(1 + \frac{L^2}{5{,}000\, r^2}\right)}$ was used for the top flanges of rolled I beams between supports, and 8,000 replaced the 9,000 when the I beams were built.

For steel members, the allowable strains in p.s.i. were as follows: for tension--14,000; for compression when the length was less than 50 times the radius of gyration--12,000; for shearing--10,000; for bending on pins--22,000; and for bearing surfaces--22,000. For steel members having radii of gyration less than 1/50 their lengths, the value in compression was determined by the same formulas as used for iron members, but tests were made to determine the constants in the formulas. No compression member was permitted a length greater than 50 diameters.

When members were subjected to alternate tensile and compressive strains, they were designed to resist both at the following allowable strains. For tension members, the values in p.s.i. were: for iron--10,000 (l – 1/2 s/S)* and for steel--14,000 (l – 1/2 s/S). 8,000 (l – 1/2 s/S) was used for iron and l2,000 (l – 1/2 s/S) for steel in compression members having a length to radius of gyration not more than 50. When this ratio was greater than 50, the numerators in the modifications of the Rankine-Gordon formula used to determine the allowable strains were 8,000 (1 – 1/2 s/S) for iron and P (l – 1/2 s/S) for steel, where P represented the numerical value derived from the results of tests on full size specimen.

For wind strain, an addition of 50 per cent was allowed to the specified limits. Lateral struts were proportioned to resist, independently of wind strains, with a factor of 5, the resultant of an initial strain of 10,000 p.s.i. in all rods attached to them.

When the shear on girder webs exceeded $\dfrac{8{,}000}{\left(1+\dfrac{d^2}{6{,}000\,t^2}\right)}$**,

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* s and S are respectively the smallest and largest of the two maximum strains regardless of sign.

** t = thickness of web and d = vertical depth between flanges.

stiffeners were to be used; the spacing was not to be greater than the depth of the girder. Stiffeners were used at the ends of girders and at all points of concentrated load.

The permissible pressure on masonry was 30,000 pounds per square foot.

In riveted work, all joints were to be fully spliced, since no reliance was to be placed upon the contact of abutting parts. Rivets were not to be used in tension. For the effective area of members, rivet, pin, and bolt holes were deducted for tension, and pin and bolt holes were deducted for compression. Rivet holes in steel had to be reamed at least 1/8 inch.

The ultimate strength for specimens taken from steel members had to be between 67,000 and 73,000 p.s.i., and they were required to have an elongation of at least 20 per cent in a length of 8 inches. They were required to be bent cold and set flat upon themselves. Each full size piece had to have an elastic limit of not less than 36,000 p.s.i., an ultimate strength of not less than 60,000 p.s.i., an elongation of 10 per cent in any 10 foot length, and was required to be bent cold 90° without sign of fracture to a curvature whose radius equaled the thickness of the piece.

As a test of the bridge, the maximum deflection under the design loads could not be greater than 1/1800 of the span.

Also in 1887, G. Bouscaren wrote “General Specifications for Highway Bridges end Viaducts of Iron and Steel.”* As far as this study is concerned this specification is the same as the one for railway bridges, with the exceptions of the live load and the allow-

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* No 36.

able stress in steel compression members with L/r ratios less than 50 subjected to alternate strains; the latter was not to exceed 11,000
(l – 1/2 s/S).

The live load was divided into three Classes--I, II, and III. Class I consisted of eighty pounds per square foot of floor plus a concentrated load for each wagon way of 30,000 pounds, uniformly distributed on a distance of 6 lineal feet. Class II had 60 pounds per square foot and a concentrated load of 22,500 pounds for each wagon way distributed over 4 1/2 lineal feet. Class III had 60 pounds per square foot and a concentrated load of 15,000 pounds for each wagon way distributed over 3 lineal feet.

The addition to live load because of impact was 30 per cent for floor beam hangers and riveted connections for floor beams and stringers, and from 5 to 15 per cent for other parts liable to impact forces.

(e) 1890.--As has been stated previously, "General Specifications for Railroad Bridges and Viaducts of Iron and Steel"* was a revised edition of the 1887 specification. G. Bouscaren also wrote this under the title of Consulting Engineer. The more important revisions will be indicated.

The clearances on a tangent were kept the same, but on curves the additional clearance in feet on each side was changed to 0.20 times the degree of curvature.

The speed that the live load should be assumed to travel was 50 miles per hour. The live load was given in three classes --A, B, and C. Class A consisted of a uniform load of 4,000 pounds per lineal foot plus two locomotives weighing 132 tons each with a load on the driver axles of 40,000 pounds, or one locomotive weighing

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* No. 52.

101 tons with a load on the driver axles of 45,000 pounds. Class B consisted of a uniform load of 3,000 pounds per lineal foot plus 2 locomotives weighing 103 1/2 tons each with a load on the driver axles of 30,000 pounds, or one locomotive weighing 91 tons with a load on the driver axles of 40,000 pounds. Class C consisted of a uniform load of 2,200 pounds per lineal foot plus 2 locomotives weighing 79 tons each with a load on the driver axles of 22,000 pounds, or one locomotive weighing 81 tons with a load on the driver axles of 35,000 pounds. The uniform load could be behind or in front of the locomotives, or in both positions, and could be continuous or discontinuous.

The additions to the live load due to the effect of impact were: for riveted connections of stringers and floor beams, and hangers not over 2 feet long--l00 per cent; for hangers over 2 feet long--50 (l + 2/L) per cent, where L = length of hanger; for girders--50 (l – d/250) per cent, where d = 1/2 length of girder; for web members of trusses, and trestle posts--50 (l – d/250) per cent, where d = distance of member from center of the truss; and for chords of trusses--50 (1 – d/250) per cent, where d = 1/2 span. In any case when d exceeded 250, no additions were made.

The allowable stresses for iron were increased in every instance, but one; the bearing value remained 15,000 p.s.i. The other values were increased to the following amounts given in p.s.i.: tension in rolled bars--12,000; tension in plates and shapes--10,000; compression where L/r ratio was less than 50--9,000; shearing across fibers--9,000; and bending on extreme fibers on pins--18,000. For iron compression members whose lengths exceeded

50 times their radii of gyration, the values in the numerators of the reduction formulas were increased 1,000 in each case.

For steel, the allowable stresses remained the same in every instance, but one; for bearing surfaces, the 22,000 p.s.i. was reduced to 18,000 p.s.i. For steel compression members whose L/r ratios were greater than 50, the formulas prescribed for iron members were used, but tests were made to determine the correct constants, and a factor of safety of 4 was required.

The design values for iron members subjected to alternate strains were changed because the base values for iron were increased. For iron in tension, 10,000 (1 – 1/2 s/S) became 12,000 (1 – 1/2 s/S). For iron in compression 8,000 (1 – 1/2 s/S) became 9,000 (1 – 1/2 s/S) which was used for members having an L/r less than 50 and in the numerator of the reduction formulas when the L/r was greater than 50.

The allowable stress on hand driven field rivets was only 3/4 of the specified limits for shearing stress.

Stiffeners were spaced at intervals equal to the depth of the girder when the shearing stress exceeded $\frac{9{,}000}{\left(1+\frac{d^2}{6{,}000\,t^2}\right)}$. This was the same as used in 1887 except 9,000 replaced the value 8,000 in the numerator. Then flange plates were used, the flange angles were as large as practicable. The pressure on rollers in pounds per lineal inch was not to exceed $700\sqrt{d}$, where d = diameter of roller in inches.

At least 1/4 inch of metal was to be planed from sheared edges of steel plates.

Rivet holes were assumed 1/8 inch larger than the diameter of the rivet. The minimum edge distance for rivets was 1 1/2 diameters. The minimum pitch for rivets was 3 diameters.

For steel, the minimum allowable values were: for ultimate strength--56,000 p.s.i., for elastic limit--33,000 p.s.i., and for elongation--10 per cent in any 10 foot length. Steel rivets had to bend cold and set flat on themselves without sign of fracture.

4. Work of C. Shaler Smith.--Although: C. Shaler Smith apparently wrote many specifications, the writer has been able to obtain only three that seem to be definitely of his authorship. Two of these are believed to have been written in 1877, and the third in 1880.

One of the 1877 specifications was prepared for the Western Union Rail Road Co.*, of which D. J. Whittemore was Consulting Engineer. According to an article published in 1905 in Volume VI of the Proceedings of the American Railway Engineering and Maintenance of Way Association**, this specification was drawn up for D. J. Whittemore, Chief Engineer, Chicago, Milwaukee and St. Paul Railway. The copy studied was received from Mr. W. H. Penfield, present chief engineer of the Chicago, Milwaukee, St Paul & Pacific Railroad Co.

The other specification of 1877*** was undated and the author not indicated. A film copy of it was obtained from the Engineering Societies Library in New York City. From a letter written by Mr. H. W. Craver, Director and Secretary, it was learned that this specification has been held by the Engineering Societies Library since 1889. Mr. W.H. Penfield and Mr. R.J. Middleton, Assistant

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* No. 11.
** No. 171.
*** No. 9.

Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad Co., recognized this specification as being one that C. Shaler Smith wrote for the Chicago, Milwaukee & St. Paul Railway Co. in 1877.

The specification believed to have been written in 1880* by C. Shaler Smith has been held by the Engineering Societies Library since that date. In a conference with Mr. R. J. Middleton, he stated that the specification was probably written by C. Shaler Smith and that the bridge for which it was prepared was built in 1883, thus indicating that 1880 was in all likelihood the correct date.

(a) 1877.--"General Specifications for Railroad Bridge to be Erected for the Western Union Rail Road Company over Rock River, near Rockton, Illinois,"** was stated in the article*** previously mentioned to be the earliest specification by C. Shaler Smith then available (1905). The clauses in the specifications which could be applied to other bridges will be enumerated below.

The clear height above the top of the rail was specified as 19 feet.

Iron to be used in tension when tested in long lengths was to have an ultimate strength of 50,000 p.s.i., an elastic limit of 26,000 p.s.i., and an elongation of 15 per cent. When cold, a 1 1/2 inch round bar was to be capable of bending 180° with no sign of fracture. Iron for compression members was required to have an elastic limit of at least 25,000 p.s.i.

In addition to the total weight of iron, 350 pounds per foot of bridge was included as dead load for the weight of rails,

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* No. 15.
** No. 11.
*** No. 171.

splices, spikes, cross-ties, and guard-timbers. The moving load was composed of a uniform load of 3,000 pounds per foot headed by an engine weighing 68 tons of which 36 tons was on 6 drivers on a wheel base of 12 feet.

The allowable strains for tension members varied from 4,000 p.s.i. for floor beam suspenders to 10,000 p.s.i. for chord members between the end panels; 8,000 p.s.i. was used for middle counter ties or the bottom chord in the end panel.

The stresses permitted for compression members were obtained from 12 modifications of the Gordon formula, depending on the type of column and the end bearings. For a common column with flat ends, the value in p.s.i. was $\frac{36{,}500}{\left(1+\frac{H^2}{2700}\right)}$ where H is the length in terms of the least diameter. The coefficient of safety applied to the above formulas was 4 + 6H/100.

The wind pressure was taken as 30 pounds per square foot on twice the truss surface as a fixed load, and 300 pounds per foot of bridge as a moving load. The lateral and vertical rods used to resist this pressure were proportioned for 15,000 p.s.i., and the lateral struts were proportioned for a safety factor of 4.

For lateral connections, the maximum shearing strain permitted was 10,000 p.s.i. and the maximum flexural strain was 22,500 p.s.i.

The effect of impact was provided for in general by adding 25 per cent to the live load, but 30 per cent was added to the live load in proportioning stringers.

The maximum strain allowed in compression was 8,000 p.s.i. and in tension was 10,000 p.s.i. The shear on rivets was not to exceed

7,500 p.s.i., and the bearing pressure was limited to 10,000 p.s.i. for pins and, rivets. For pins, the shear should not be over 7,000 p.s.i., and the bending strain was never to be more than 15,000 p.s.i.

In riveted work, all joints were required to be square and truly dressed. Rivets were required to completely fill the holes. In posts and chords, the connecting rivets within a distance of 2 diameters of the member from its end were required to have an area equal to the section area of the joined pieces. The maximum longitudinal spacing of rivets in riveted work was not to exceed 16 times the thickness of the thinnest plate joined by them, and the maximum distance between rivets across a plate was 30 times the thickness of the plate. All abutting joints were to planed true.

The greatest pressure allowed on masonry was 25,000 pounds per square foot. The maximum strain in pounds per lineal inch on rollers was $\sqrt{540{,}000\ d}$, where d = diameter of roller in inches.

The permanent camber required was not less than 1/1200 of the span. No permanent set was permitted under the test load (which consisted of an engine, tender, and 15 loaded freight cars), whether moving or stopping suddenly.

(b) Also 1877.--"General Specifications for Railway and Highway Bridge Combined, to be Erected for the Chicago, Milwaukee and St. Paul Railway Company, over the Wisconsin River at Kilbourn City, Wisconsin,"* could be applied to bridges in general in many respects. The few requirements in this specification, other than those pertaining to loads for highway bridges, that do not agree with the preceding ones, will be given.

For live load, a uniform load of from 3,500 to 4,000 pounds

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* No. 9.

per foot of bridge, depending on the span, was used along with a weight of 72,000 pounds on a distance of 12 ft.; however, for the 247 ft. span of this particular bridge, only a uniform load of 3,100 pounds per foot of bridge was used. To the strains computed for the combined live and dead loads was added 8 per cent for members in the end panel, and 6 per cent for members in the second, or second and third panels, depending on the length of the bridge.

For floor beams and stringers, the live load specified was the same as given for (a), with a similar addition for impact.

The pressure permitted on the masonry was 35,000 pounds per square foot for the main span and 25,000 for the smaller spans.

(c) 1880.--"General Specifications for a Wrought Iron Railway Bridge to be Erected for the Joint Use of the Chicago & North Western and the Chicago, Milwaukee & St. Paul Railway Companies Over Rock River at Janesville, Wisconsin,"* like the two previous specifications, was for a specific bridge; however, some of the information is pertinent to this study. Values that already have been quoted from Mr. Smith's work will not be repeated.

For members exposed to strains in opposite direction, the sections were determined by:

$$S = \frac{\text{Maximum Tension}}{10{,}000} + \frac{\text{Maximum Compression}}{\left(\frac{\text{Column Strength per sq. in.}}{4}\right)}$$

in which S represented the sectional area in square inches, and the column strength per square inch of sectional area was determined from the appropriate modification of the Rankine-Gordon formula. S was not used as the sectional area if it was less than the area required for a tension member or a compression member.

* No. 15.

The modifications of the Rankine-Gordon formula were the same as indicated previously, but the coefficient of safety was 4 plus 5H/100 rather than 4 plus 6H/100.

The bearing pressure allowed on pins and rivets was reduced from 10,000 to 8,000 p.s.i. The shearing strain permitted on pins was increased from 7,000 to 7,500 p.s.i., the value used for rivets.

The minimum pitch for rivets was 2 1/2 diameters and the maximum was 9 inches or 16 times the thickness of the thinnest outside plate. The least edge distance for rivets was 1 1/4 inches or 1 3/4 diameters to the end of a plate and 1 1/2 diameters to the side of a plate. When two or more plates were riveted together, the outer row of rivets was not permitted to be more than 3 diameters from the edge of any plate.

5. Work of Chas. Hilton, in 1877.--"Specifications for Wrought Iron Railroad Bridges"* was received from B. R. Leffler, Bridge Engineer, New York Central Railroad Company. It was written in 1877 for the Lake Shore & Michigan Southern Railway. The material in this specification agrees with that given in an article** written by a committee of the American Railway Engineering and Maintenance of Way Association which was stated to have come from a specification written by Chas. Hilton in 1877 for the Lake Shore & Michigan Southern. The writer is convinced that this specification was the work of Chas. Hilton, and lists in the following paragraphs the portions that were of interest.

The paragraph describing the live load used for all parts of

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* No. 10.
** No. 171.

the bridge is given here.

> A moving load on each track consisting of two locomotive engines coupled together and drawing a train of cars long enough to cover the longest span of bridge; the whole train weighing 2250 lbs. per foot of length, with an additional weight for each engine sufficient to make a load of 90,000 lbs. concentrated upon three pairs of driving wheels spaced seven feet apart between centers of axles; each engine being assumed to occupy fifty feet of the length of the train.

For the computations of strains in the several members of the main girders or trusses, a uniform load, varying from 6,000 pounds per lineal foot for a 10 foot span to 2,500 pounds per lineal foot for a 500 foot span, was used with an additional panel load of 20,000 pounds at the head of the uniform load. For spans less than 10 feet in length, a load of 30,000 pounds on one pair of driving wheels (one axle) was used.

Through bridges had a clear height of 19 feet above the rails and a clear width of 14 feet. All bridges were required to have a width at least equal to 1/15 of the span. Girders were used for spans less than 50 feet in length, and had a depth equal to at least 1/10 of the span.

The entire floor system was to be capable of supporting the locomotive described above at any place on the floor, with a factor of safety of 8.

A lateral force of 300 pounds per lineal foot of bridge was used as a design load for the lateral bracing at the floor level, and a lateral force of 150 pounds per lineal foot was assumed on the other lateral bracing. In every case, the top and bottom lateral bracing together were to be capable of resisting a lateral force of 30,000 pounds.

The required minimum elastic limit was 26,000 p.s.i., and the minimum ultimate strength was 55,000 p.s.i. for all material but plates which had to have a strength of only 45,000 p.s.i. A specimen of iron 1 inch thick was to be capable of being bent double without fracture.

The allowable strain in tension on the net section for members of the main trusses and girders was 7,500 p.s.i., but floor beam hangers were permitted only 5,500 p.s.i. For a member in compression, the greatest strain permitted was 1/7 of its ultimate strength.

Rivets were to be made of iron required to have an ultimate strength of 60,000 p.s.i. The minimum pitch permitted for rivets was 2 1/2 diameters; the maximum pitch was 9 inches or 12 times the thickness of the thinnest outside plate; and the edge distance was to at least 1 1/4 inches or 1 3/4 diameters. When two or more plates were riveted together, a row of rivets within 2 inches of either edge was required. The shearing strain allowed on rivets was 6,000 p.s.i., and the permissible bearing pressure was 8,500 p.s.i. Since no reliance was placed on abutting surfaces, all joints had to be fully spliced.

The shear on webs of girders was not to exceed 4,000 p.s.i. The webs were to be stiffened with angles or tees to prevent buckling. No plate iron less than 5/16 inches thick was permitted.

The maximum pressure permitted on masonry was 250 p.s.i.

For bridges over 50 feet in length, expansion rollers were used, the pressure on which was limited to 300 pounds per lineal inch for each inch of diameter of roller.

6. Work of Theodore Cooper.--According to information received in a letter from Mr. G. S. Fanning, Chief Engineer, Erie Railroad Company, Theodore Cooper had a hand in drafting specifications for the New York, Lake Erie and Western Railroad Co., which was the former name of the Erie Railroad. A specification for this company dated 1878* contained some handwriting said by Dr. O. E. Hovey to be that of Theodore Cooper. The following statement was taken from "Historical Sketch of the Development of American Bridge Specifications"**: "In 1879 Mr. Octave Chanute, Chief Engineer of the Erie, published the famous specification drawn by Theodore Cooper. This was designed to be general for all track bridges on the Erie road." This evidence has convinced the writer that Mr. Cooper was the author of the l879*** specifications, and author or coauthor of those of l878. *

As a Consulting Engineer, Mr. Cooper wrote specifications for railway bridges in 1884, 1885, 1890, 1896, and 1901, and for highway bridges in 1890, 1896, and 1901. In Strains in Framed Structures**** by A. Jay DuBois, one of Cooper's specifications was given under the date of 1888; however, this was found to be the same as the one published separately in 1890.

(a) 1878.--"Specifications for Iron Bridges"* was the only Cooper specification found that did not have an engine with concentrated wheel loads as part of the live load.

The track was taken as weighing 400 pounds per lineal foot. The moving load varied from 5,300 pounds per foot of track for

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* No. 12.
** No. 171.
*** No. 13.
**** No. 47.

transverse beams and 8,800 for stringers, girders, or trusses for spans of 5 feet, to 3,400 pounds per foot of track for transverse beams and. 4,200 for stringers, girders, or trusses for spans of 30 to 35 feet. For spans of 35 to 50 feet, 4,000 pounds per foot of track *was* used for girders and trusses. Ten per cent was deducted from this load, for the center truss in three-truss, double track, through bridges.

Truss bridges were used for spans over 50 feet in length. For through bridges, there was specified a clear width of 15 feet, and a clear height of 19 feet above the rails.

For iron used in tension, the material requirements were: for ultimate strength, not less than 50,000 p.s.i.; for elastic limit, at least 22,000; for elongation, an average of 15 per cent; and a 1 1/2 inch bar should bend to a curvature having a radius 1 1/2 times its thickness without evidence of fracture.

In tension, the following strains in p.s.i. were the maximum allowed: on the bottom chord and main tie rods--10,000; on long suspenders and counter rods--8,000; and on floor beam hangers--6,000 p.s.i. The form $\frac{40,000}{\left(1+\frac{L^2}{40,000\,r^2}\right)}$ with a factor of safety of 5 was used for the allowable strains in p.s.i. in compression members with square ends, and 25 per cent was deducted from this value for each pin joint. Members subjected alternately to tension and compression were proportioned to resist the sum of the strains.

The maximum shearing strain permitted on pins or rivets was 6,000 p.s.i., and bending strain on pins was limited to 15,000 p.s.i. The effective length of any pin was not to be greater than the breadth of the foot of the post plus 4 diameters of the pin. The limiting pressure for pins or rivets was 12,000 p.s.i.

Lateral rods were permitted to vary in size from 1 to 1 1/2 inches, depending on length of span in which they were to be used. The shearing strain allowed in lateral connections was 10,000 p.s.i. The compressive strain in p.s.i. in lateral struts was not allowed to exceed $\frac{10,000}{\left(1+\frac{L^2}{40,000\,r^2}\right)}$.

The webs of girders were proportioned to take all of the shearing strain, and the top and bottom flanges were assumed to resist all the bending. The web was not permitted to be less than 1/4 inch thick, nor to be strained in shear to more than 6,000 p.s.i. The strain in the upper flange was not to exceed 8,000 p.s.i., and in the lower flange, 10,000 p.s.i. on the net section.

The maximum pitch permitted for rivets was 6 inches, and the minimum pitch permitted was 3 diameters of the rivet holes. The minimum edge distance was 1 1/2 diameters of the rivet.

Joints in compression and tension had to be square and fully spliced. At the end of a compression member for a length equal to two diameters of the member, the maximum rivet pitch permitted was 3 inches.

For plate iron, the requirement for ultimate strength was 45,000 p.s.i., for the elastic limit 20,000 p.s.i., and for elongation 12 per cent.

The maximum pressure allowed on masonry was 250 p.s.i. For bridges over 50 feet in length, turned rollers were used at one end, the weight on which was not to exceed 300 pounds per lineal inch for each inch of roller diameter.

The camber was to be such that under maximum load, the bridge would not deflect below a horizontal line.

(b) 1879.--"General Specification for Iron Bridges"* was written for and used by the New York, Lake Erie & Western Railroad Co., as was the previous specification. The engine that appeared in this specification, as part of the live load, was similar to what might have been classed as E-22 by the classifications that Theodore Cooper later adopted. Requirements common to both specifications that have been indicated for the preceding one, will not be repeated for this one.

Rolled beams were preferred for spans up to 17 feet, riveted plate girders from 17 to 40 feet, riveted lattice girders from 40 to 75 feet, and pin connected trusses for spans over 75 feet.

The clear distance required above the base of rails was 20 feet.

The live load consisted of two "consolidation" engines coupled, followed by a uniform load of 2,240 pounds per running foot. The engines weighed 80.67 tons each, with 22,000 pounds on each of 4 driving axles.

The lateral bracing at the floor level was designed for a lateral force of 450 pounds per foot of span, of which 300 pounds was treated as moving load. The other lateral bracing was proportioned to resist 150 pounds per foot of span.

A temperature variation of 150 degrees was to be provided for in all parts of the bridge.

Steel was allowed as a substitute for iron if evidence of the

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* No. 13.

demanded quality was furnished.

The maximum strains allowed for tension members varied from 6,000 p.s.i. for floor beam hangers, to 10,000 p.s.i. for rolled beams, bottom chords, and main diagonals; but on lateral bracing, 15,000 p.s.i. was permitted.

For compression members, the reduction formula used for square ends was $P = \dfrac{8,000}{\left(1 + \dfrac{L^2}{40,000\ r^2}\right)}$. If one end was a pin bearing, 30,000 replaced 40,000, and if both ends had pin bearings, 20,000 replaced 40,000. Lateral struts were proportioned by these formulas to resist the resultant of an assumed initial tension of 10,000 p.s.i. in all rods attached to them. For compression in girders, the allowable value varied from 10,000 p.s.i. for rolled beams used as cross floor beams, to 5,000 p.s.i. for riveted longitudinal plate girders less than 20 feet long.

Members subjected to alternate strains of tension and compression were designed to resist each strain plus 8/10 of the smaller.

The shear was limited to 6,000 p.s.i. on rivets and 7,500 p.s.i. on pins. The crushing strain allowed on pins and rivets was 12,000 p.s.i., and the bending strain permitted on pins was 15,000 p.s.i.

Compression flanges of beams and girders had to be supported against crippling when their lengths were more than 30 times their widths. The maximum unsupported width permitted for any plate was 30 times its thickness. The shearing strain in webs was not to exceed 4,000 p.s.i., and the webs were not to be less than 1/4 inch thick. Stiffeners were required at intervals not over twice the depth of the girder, when the thickness of the web was less than 1/80 of the girder depth.

The maximum pitch of rivets was not to exceed 6 inches (as required in 1878) or 16 times the thickness of the thinnest outside plate. The minimum edge distance allowed was 1 1/4 inches, except for bars less then 2 1/2 inches wide; and 2 diameters was used when practicable. When plates over 12 inches wide were used in flanges, an extra line of rivets, with a pitch not more than 9 inches, was driven along each edge. For a length of two diameters at the end of compression member, the maximum rivet pitch allowed was 4 diameters of the rivets.

Turned friction rollers had to be at least 2 inches in diameter and proportioned so that the maximum pressure per lineal inch of roller did not exceed 500 pounds times the square root of the roller diameter in inches.

All bridges were given a camber, by making the top chord longer then the bottom chord in the proportion of 1/8 inch to every 10 feet of panel length.

All wrought iron was required to have an elastic limit of not less than 26,000 p.s.i. Specimens taken from various sizes and shapes had to have ultimate strengths from 48,000 to 52,000 p.s.i., and elongations 15 per cent or more in a length of 8 inches. Iron for tension members had to be capable of being bent cold, 90 degrees around a curvature whose radius equaled the thickness of the metal, without cracking. At least one in three had to bend 180 degrees.

(c) 1884.--"General Specifications for Iron Railroad Bridges and Viaducts"* was issued in three forms, namely, Class A, Class B, and Class C. The only difference of any consequence in the three was in the live load. Only important changes or additions to (a) and (b) will be noted below.

For Class A, the live load was composed of two engines, weighing 85.5 tons each, followed by a uniform load of 3,000 pounds per running foot. The weight on each of 4 driver axles was 24,000 pounds. An assumed 80,000 pounds on two pairs of drivers, seven feet center to center, could be used to substitute for the two engines.

Class B specified a train weighing 2,240 pounds per foot preceded by two engines, weighing 80.5 tons each, having 22,000 pounds on each of 4 driver axles. The engines were replaced by a load of 80,000 pounds on two pairs of drivers, 7 1/2 feet apart, if this gave a greater stress.

Class C consisted of a train weighing 2,000 pounds per foot plus two, 72 ton engines, each having a 25,000 pound load on each of three driver axles; or 80,000 pounds equally distributed upon two pairs of drivers, 8 feet center to center.

The material that follows was common to all three classes.

Riveted plate girders were used for spans from 16 to 60 feet, riveted trusses from 60 to 90 feet, and pin connected trusses for spans over 90 feet. The minimum clear width required for through bridges was reduced to 14 feet.

The bracing in trestle towers was to be proportioned to resist wind pressure given as: (1) with the trusses loaded, a pressure at track level of 650 pounds for each horizontal foot of

* No. 23, 24, and 25.

structure, and 125 pounds for each vertical foot of the bents; or (2) with the trusses unloaded, a 600 pound pressure at track level for each horizontal foot of the structure, and 225 pounds for each vertical foot of the bents.

The bracing was to be capable of resisting the greatest tractive force of the engines, or forces induced by sudden stops, taking the coefficient of friction of wheels against rails as 0.20. For bridges on curves, the additional effect of centrifugal force of trains moving at high velocities was considered.

The allowable strain in tension or compression for rolled beams was 8,000 p.s.i. The shear permitted on pins or rivets was 7,500 p.s.i.

For spans over 150 feet, the given values for tension and compression in chord members were increased by the following amount:
$\left(\frac{150 \times \text{its strain from dead load}}{\text{Its strain from dead and live load}} - 50\right)$ percent. An increase in values of 25 per cent was allowed when the effect of wind was included as one of the forces resisted by the bridge.

The minimum thickness of web plates was 3/8 inches. Stiffeners were to be spaced at intervals, about the depth of the girders, whenever the shearing strain in p.s.i. exceed $\frac{12{,}000}{\left(1 + \frac{H^2}{3{,}000}\right)}$, where H was the ratio of the depth of the web to its thickness. Stiffeners were required over points of bearing or under local concentrated loadings.

Rivets were not to be used in tension. When driven, they were required to completely fill the holes. Field rivets had allowable strain values 1/3 less than shop rivets.

Requirements were specified for batten plates and latticing used on compression members.

The greatest pressure allowed on masonry under bed plates was 200 p.s.i. The shortest span required to have turned friction rollers at one end was increased to 75 feet.

(d) 1885.--"General Specifications for Iron Railroad Bridges and Viaducts"* was essentially a reissue of the 1884 specification, giving all three classes of loadings in the one specification.

One additional requirement was inserted which would affect some of the tension members; namely, that angles subjected to direct tension which were connected by only one leg would have as effective area, the section of that leg only.

(e) 1890.--"General Specifications for Iron and Steel Railroad Bridges and Viaducts"** was the first of Cooper's railway bridge specifications to include definite requirements for steel. He divided steel into two grades, namely, soft steel and medium steel. The following paragraphs contain most of the significant revisions and additions to the Cooper specifications already abstracted.

The live load was divided into five classes, viz., Lehigh Heavy Grade Engine Class, Class Extra Heavy A, Class A, Class B, and Class C. Each type of loading consisted of two "consolidation" locomotives coupled, followed by a uniform load, or a heavy load equally distributed upon two pairs of drivers. In the order given, the weights of engines specified from each class were 126, 104, 85.5, 80.5, and 72 tons respectively, the uniform loads specified

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* No. 28.

** No. 54.

were 4000, 3000, 3000, 2240, and 2000 pounds per lineal foot respectively, and the substitute heavy loads, 100,000 pounds for Lehigh Heavy Grade and 80,000 pounds for the other four classes but the axle spacing varied as follows: 7, 7, 7, 7 1/2, and 8 feet respectively.

When forged eyebars were used as bottom chords, main diagonals, counters, and long verticals, the strain allowed was 8,000 p.s.i. for live loads or 16,000 p.s.i. for dead loads; but when plates or shapes were used for the same members or bottom flanges, the strain was limited to 7,500 p.s.i. for live load and 15,000 p.s.i. for dead load.

The formulas used in proportioning compression members were;

P = 8,000 – 30 L/r for live load strains in chord segments; P = 7,000 – L/r for live load strains in all posts; P = 10,500 – 60 L/r for wind strains in all posts; and P = 9,000 – 50 L/r for assumed initial strains in lateral struts. The permissible strains for dead load were double those for live load. The maximum length that a compression member could have was equal to 45 times its least width.

If the bending strain in any member due to its own weight exceeded ten per cent of the allowable strain on that member, the excess was to be considered in the design of the member.

In figuring net section, the rivet holes were assumed 1/8 inch greater in diameter than the undriven rivets.

Abutting joints with planed faces in compression members were to be spliced sufficiently to insure the contact areas against any displacement.

Flange plates used in girders were required to be of equal or less thickness outward from the angles. When girders had flange plates, at least 1/2 of the flange section was required to be in the angles unless the largest sized angles were used. Cover plates of top chords and end posts were permitted unsupported widths of 40 times their thicknesses, but all other plates subjected to compression were limited in width to 30 times their thicknesses. Only one cover plate was to be used, and its thickness was not to be more than 1/2 inch, except when necessary to resist bending strains.

The greatest pressure allowed on masonry was 250 p.s.i.

Soft steel was permitted under the same conditions as wrought iron for all riveted work, if a rivet hole in the soft steel could be drifted to a diameter 25 per cent greater than the original diameter without cracking.

Medium steel for tension members, chords, or girders was allowed strains 20 per cent more than those permitted for wrought iron. For all posts, the allowable strains were calculated from the following formulas, if sheared edges were planed 1/4 inch and punched holes sub-punched 1/8 inch and reamed to size; P = 8,500 – 55 L/r for live load, P = 17,000 – 110 L/r for dead load, and P = 13,000 – 85 L/r for wind strains.

Rivets of iron or steel were to be capable of being bent double to a close contact without sign of fracture.

For medium steel test specimens, the ultimate strength had to be from 62,000 to 68,000 p.s.i.; the elastic limit, not less than 33,000 p.s.i.; and the elongation, at least 20 per cent in 8 inches.

For soft steel test specimens, the comparable qualities were specified as 54,000 to 62,000 p.s.i., not less than 30,000, and at least 25 per cent in 8 inches respectively.

Cooper's "General Specifications for Iron and Steel Highway Bridges and Viaducts"* was the first general specification found, devoted entirely to highway structures. It was similar in content to Cooper's specification for railway bridges as far as the items of material and workmanship were concerned, but the allowable strain values were larger, and the live load was very different.

(f) 1896.--"General Specifications for Steel Railroad Bridges and Viaducts"** was the first of the specifications by Cooper which contained his class E series of loadings, and also the first that applied only to steel. These two variations comprise the major differences between these and the preceding specifications. However, other differences of importance will be mentioned.

Rolled beams were preferred for spans up to 20 feet, plate girders for spans of 20 to 75 feet, plate girders or lattice girders for spans of 75 to 120 feet, lattice or pin connected trusses for spans of 120 to 150 feet, and pin connected trusses for spans over 150 feet.

The clear height above the base of rails was increased to 21 feet.

The live loads indicated were E 27, E 30, E 35, and E 40. A 100,000 pound load equally distributed on two pairs of axles 7 1/2 feet apart was used as an alternate live load for all the parts of the structure.

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* No. 53.
** No. 88.

The wind pressure was increased 10 pounds per foot of span for each 30 feet of span over 300 feet. The 300 pounds per foot of the wind pressure treated as moving load was assumed to act 8 1/2 feet above base of rail.

The centrifugal force for structures on curves was computed for a speed, in miles per hour, of 50 minus twice the degree of curvature, and was assumed to act 5 feet above base of rail.

The allowable strains were changed some. For medium steel in tension, the maximum live load strain was 10,000 p.s.i., except for bracing which was permitted 18,000 p.s.i. The tension in floor beam hangers, fabricated from plates or shapes, was limited to 6,000 p.s.i. Soft steel used in tension was permitted unit strains 10 per cent less than those specified for medium steel.

The reduction formulas used for medium steel members in compression were; P = 10,000 – 45 L/r for chord segments, P = 8,500 – 45 L/r for posts of through bridges, and P = 9,000 – 40 L/r for posts in trestles or deck bridges. These were for live load strains, and values twice as great were permitted for dead load strains. For wind strains in lateral struts, the formula was P = 13,000 – 70 L/r. End posts were not considered as chord segments. For soft steel, compressive strains were reduced 15 per cent. No compression member was permitted a length more than 125 times its least radius of gyration.

For pins and rivets, the allowable shearing and bearing strains were 9,000 p.s.i. and 15,000 p.s.i. respectively. Only 80 per cent of these values were permitted for rivets in members of the floor system, and an excess of 50 per cent was permitted for rivets in bracing. The bending strain on pins was not to be more than 18,000 p.s.i.

"The rupture of a riveted tension member is to be considered as equally probable, either through a transverse line of rivet-holes or through a diagonal line of rivet-holes, where the net section does not exceed by 30 per cent the net section along the transverse line.

The number of rivet-holes to be deducted for net section will be determined by this condition."*

Compression flanges of girders were to be laterally supported at intervals not over 20 times their widths.

Turned friction rollers were to be at least 2 7/8 inches in diameter, and the pressure per lineal inch of roller was not to exceed 300 pounds times the diameter in inches.

Planing of sheared edges was not required, nor reaming of punched holes, if a punched hole could be drifted to a diameter 1/3 greater then that of the original hole without cracking.

The ultimate strength for medium steel was to be from 60,000 to 68,000 p.s.i. and for soft steel 54,000 to 62,000 p.s.i., with the elastic limit at least 1/2 of the ultimate strength in every case. The ultimate strength of full sized eyebars was to be 56,000 p.s.i. or more.

(g) 190l.--The revisions and additions to the 1896 edition under the same title, "General Specifications for Steel Railroad Bridges and Viaduct,"** were few, but in most respects will be given below.

E50 was added to the live load specification, and the alternate load used for classes above E 40 was 120,000 pounds equally

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* No. 88, p. 12.
** No. 131.

distributed on two pairs of axles 6 feet apart.

The assumed speed of trains used in the computation of centrifugal force was, in miles per hour, 60 minus 3 times the degree of curvature.

For compression members, the lengths were limited to 100 times the radii of gyration for main members, and 120 times for laterals.

The maximum values for strains were increased 30 per cent when the effect of wind pressure was included in the design.

Stiffeners were required on girder webs, at intervals not more then 5 feet or the depth of the girders, whenever the shearing strain exceeded the value obtained from the formula: $P = 10{,}000 - 75\ H$, where H was the ratio of depth to thickness for the web. Each stiffener was to be capable of resisting the maximum vertical shear at a unit strain not more than that found from: $P = 10{,}000 - 45\ L/r$.

Counters were to be proportioned so that an increase of 25 per cent in the specified live load would not give a unit strain over 25 per cent more than the amount allowed.

Supports were required for compression flanges at intervals not greater than 16 times the width of the flange.

If the unsupported width of a cover plate was over 40 times its thickness, only 40 times the thickness was considered as effective area.

Rivet steel was required to have an ultimate strength of 50,000 to 58,000 p.s.i., a yield point of 1/2 the ultimate strength, and an elongation of not less than 26 per cent in 8 inches.

7. <u>Pennsylvania. Railroad Co</u>.--The specifications issued by the

Pennsylvania Railroad Co. that the writer has been able to obtain include those dated 1884, 1887, 1897, and 1901, also one dated 1901 with corrections to 1905. In 1885, Mr. J. M. Wilson presented a set of specifications* before the American Society of Civil Engineers which was very similar to the specification of 1884.

The first specification found for the Pennsylvania Railroad, although early, was quite complete, consequently the later development of specifications for the Pennsylvania Railroad was more a matter of changing limitations than adding limitations. However, much was added between 1884 and 1901.

Only the most distinguishing characteristics of the Pennsylvania Railroad's specifications will be mentioned in the following paragraphs.

(a) 1884.--"Specifications for the Strength of Iron Bridges** was written by J. M. Wilson, Engineer of Bridges and Buildings, Pennsylvania Railroad.

The live load consisted of two consolidation engines coupled, weighing 86 tons each, two passenger engines coupled, weighing 88 tons each, or one class "M" engine, weighing 66 1/2 tons, but each of these three engine loadings was followed by a train weighing 3,000 pounds per lineal foot.

The limiting stresses for tension and compression members were obtained from what the specification termed "Launhardt's formula." For pieces subjected to either tension or compression, the form $a = u\left(1 + \frac{\text{minimum stress in member}}{2 \times \text{maximum stress in member}}\right)$ was used; and for pieces subjected to both tension and compression, the form $a = u\left(1 - \frac{\text{maximum stress of lesser kind}}{2 \times \text{maximum stress of greater kind}}\right)$ was used. In these formulas, "a" was the permissible stress in p.s.i. and "u"

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* No. 31.
** No. 26.

was 9,000 p.s.i. for bars in tension, 8,500 for plates or shapes in tension, and 7,500 for compression members. The permissible stress "a" for members in compression was reduced by one of three modifications of the Rankine-Gordon formula, depending on the type of end bearing. For a member with both ends fixed, the allowable working stress was $\frac{a}{\left(1+\frac{L^2}{36{,}000\,r^2}\right)}$.

Floor beam hangers were required to have sections 50 per cent greater than those given by the permissible stresses in tension.

When the upper flanges of girders were unsupported for a distance exceeding 12 times their widths, the working stresses were reduced according to the following formula: allowable working stress = $\frac{a}{\left(1+\frac{L^2}{5{,}000\,b^2}\right)}$, where b was the flange width in inches.

When the unsupported distance between chord angles was over $^1/_{30}$ the thickness of the girder web, stiffeners were spaced at intervals not greater than the full depth of the web or a maximum of 5 feet.

(b) <u>1887</u>.--"Standard Specifications for Wrought Iron Bridges"* was signed by "Wm. H. Brown, Chief Engineer, Pennsylvania Railroad."

The permissible stress for members subjected to either tension or compression was determined from the formula $a = u(l + r)$; and for members subjected to both tension and compression, the formula was $a = u(1 - r_1)$. "a" was the permissible stress in p.s.i.; "u" was 7,500 p.s.i. for bars in tension, 7,000 for plates or shapes in tension, and 6,500 for compression members; "r" was

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* No. 43.

$\frac{\text{Minimum stress in member}}{\text{Maximum stress in member}}$; and "$r_1$" was $\frac{\text{Maximum stress of lesser kind}}{2x\text{ Maximum stress of greater kind}}$.

The clauses concerning net section of tension flanges were the same as J. M, Wilson included in his paper presented before the American Society of Civil Engineers in 1885*, namely,

> In calculating the net sections of flange angles in tension in plate girders, all the rows of rivets must be deducted except in the case of staggered rivets having a pitch (measured between rivets in the same row) of two or more times the distance between rows of rivets; and in flange plates having rivets staggered, all rows must be deducted unless so arranged that the net section along a zigzag line, taking all distances in a diagonal direction at only three-fourths their value, exceeds the corresponding net section directly across the plate.**

(c) 1897--Standard Specifications for Steel Bridges"*** was written by Wm. H. Brown and Wm. A. Pratt, Chief Engineer and Engineer of Bridges, respectively, of the Pennsylvania Railroad Co.

The formula for the calculation of centrifugal force in pounds per lineal foot for curvatures of 5 degrees or less was: Centrifugal force $= 176\,D\left(1+\frac{30}{s}\right)$, where D was the degree of curvature and S was the span in feet. The coefficient (176) was reduced by 10 for each degree of curvature over 5 degrees.

The maximum calculated strain (M) in each member was increased by a quantity kM. The coefficient (k) was equal to $\frac{1-R}{1+R}$ for members that had all tension or compression, and was equal to $\frac{2+R}{2-R}$ for members subjected to reversal. The quantity R was the ratio m/M where m was the minimum calculated strain for members subjected to only one kind of stress, or was the maximum calculated

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* No. 31.
** No. 43, paragraph 61.
*** No. 99.

strain of the lesser kind for members subjected to reversal.

Compression members were allowed unsupported widths of not more than 50 times their thicknesses.

Stiffeners were required to be spaced not farther apart than the depth of the web plate or a maximum of 5 feet, when the thickness of the web was less than 1/60 of the unsupported distance between flanges.

In calculating net section, rivet holes were assumed 1/8 inch larger in diameter than the nominal size of the rivets, but no specific procedure was indicated which would determine the transverse sections to use in finding the net section, as was given in the previous specifications.

(d) <u>1901</u>.-- "Standard Specifications for Steel Bridges"* was written by the same men who wrote the 1897 specification, but H.R. Leonard, Engineer of Bridges, along with Wm. H. Brown was responsible for the corrections made in 1905** to those of 1901.

Essentially, the 1901 specification had clauses similar to the 1897 specification.

In 1905, the coefficient k, used in 1897, was changed and made equal to $1 - 2R + R^2$ for members that had one kind of stress only, and to $1 + 2R - R^2$ for members subjected to reversal.

8. <u>Baltimore and Ohio Railroad Co</u>.--The Baltimore and Ohio Railroad Company issued specifications in 1885, 1889, 1894, 1896, 1901, and 1904. In 1889, the title was "Specifications for Workmanship and Quality of Material for Wrought Iron and Steel Bridges"* * *; and

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* No. 138.
** No. 176.
*** No. 50.

the specification did not contain any requirements for the control of design. Two separate specifications were printed in 1904, but the one entitled, "Specifications for Material and Workmanship for Steel Structures,"* was identical with the specifications adopted by the American Railway Engineering and Maintenance of Way Association in l903.**

The Baltimore and Ohio specifications had some unusual clauses which will be given in the following paragraphs.

(a) 1885.-- "Specifications for Wrought Iron Bridges"*** required members subjected to alternate strains of tension and compression to be proportioned to resist each kind of strain, as given verbatim.

For short columns (Weyrauch's formula)

$$B = u\left(1 - \frac{2}{5}\,\frac{\text{strain of lesser kind}}{\text{strain of greater kind}}\right)$$

$$P = \frac{\text{strain of great kind}}{B}.$$

For long columns (Weyrauch's formula adapted by DuBois)

When compressive strain is greatest

$$B = u\left(1 - \frac{2}{5}\,\frac{\text{Max. tensile strain.}}{\left(1 + \frac{L^2}{cr^2}\right)\text{Max. compressive strain.}}\right)$$

$$P = \frac{\left(1 + \frac{L^2}{cr^2}\right)\text{Max. compressive strain.}}{B}$$

When tensile strain is greatest

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* No. 164.

** No. 155.

*** No. 27.

$$B = u\left[1 - \frac{2}{5}\,\frac{\left(1+\frac{L^2}{cr^2}\right)\text{Max. compressive strain.}}{\text{Max. tensile strain.}}\right]$$

$$P = \frac{\text{Max. tensile strain.}}{B}.$$

P = sectional area required.
B = working strain per square inch.
u = 8000.
L = length of column in inches.
c = 36,000 for square ends, 24,000 for square and pin, 18,000 for pin ends.
r = least radius of gyration of section in inches.

The webs of plate girders were to be stiffened on both sides with angles, at intervals not greater than the depth of the web with a maximum of 5 feet, whenever the shearing strain in p.s.i. exceeded $\frac{8,000}{\left(1+\frac{d^2}{3,000\,t^2}\right)}$ where d was the effective depth in inches times the secant 45 degrees, and t was the thickness of the web in inches.

The lateral wind pressure was assumed to be 35 pounds per square foot of exposed surface.

(b) 1894.--"Standard Specifications for Iron and Steel Bridges and Viaducts"* was written by J. E. Greiner, Engineer of Bridges.

In these specifications, when the unsupported depth of any girder web was greater than 60 times the web thickness, intermediate stiffeners ware spaced so that their distances, center to center, would not exceed the depth of the girder, nor a maximum limit of 5 feet.

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* No. 68.

The net section of any member or flange in tension was to be determined by a transverse plane at any point: the greatest number of rivet holes cut by or within an inch of that plane were to be deducted from the gross section. Each hole was taken as 1/8 inch greater in diameter than the rivet.

For eyebars of medium steel, the maximum permissible unit stress in tension in p.s.i. was $9{,}400\left(1+\frac{\text{min.}}{\text{max.}}\right)$. For compression chords of medium steel, the maximum unit stress in p.s.i. was $8{,}400\left(1+\frac{\text{min.}}{\text{max.}}\right)-45\frac{L}{r}$. For members of medium steel subjected to alternate tensile and compressive stresses, the allowable stress in compression was 8,400 – 45 L/r, and the allowable stress in tension was $9{,}400\left(1-\frac{\text{max. lesser stress}}{2\text{x max. greater stress}}\right)$. The same types of formulas were used for members of iron or soft steel but with different constants.

The unsupported width of a cover plate, was to be not greater than 50 times its thickness.

When a track was on a curve, both inner and outer trusses were to be alike, and proportioned to resist the live load given by the following formula: $W=\left(\frac{m+b}{2b}\right)P$, where W was the load for either truss, m was the center ordinate to the curve, b was width center to center of trusses, and P was the live load at the panel considered.

The effect of wind on chords, end posts, or trestle legs was considered only when the wind stresses were greater than 50 per cent of all other stresses; or when the wind stresses alone, or in combination with temperature stresses, could neutralize or reverse the live load and dead load stresses.

(c) 1896, 1901, and 1904.--J. E. Greiner, Engineer of Bridges for the Baltimore and Ohio Railroad, wrote "General Specifications for Railroad and Highway Bridges, Roofs and Buildings"* in 1896, "General Specifications for Railroad and Highway Bridges, Roofs and Steel Buildings"** in 1901, and "Specifications for the Design and Erection of Bridges"*** in 1904.

In the 1896 specification, the minimum pitch of rivets was limited to 3 1/2 diameters when on the same line, or 2 1/2 diameters when staggered.

In the 1901 specification, upper chords of trusses were to have a single cover plate which was to be at least 3/8 inch thick or have a thickness not less than 1/60 the width between connecting rivets.

Also in the 1901 specification, the following impact formula was given: $I = S\left(\frac{300}{L+300}\right)$, where I was the impact, S was calculated maximum live load strain, and L was the length of loading which produced maximum strain in the member. This is the same formula that C. C. Schneider used in the Pencoyd Iron Works' specifications of 1895.**** In "General Specifications for Railroad Bridges"***** issued by the Pencoyd Iron Works in 1887, Mr. Schneider had used the impact formula, $I = S\left(.7 + \frac{5}{L}\right)$; but according to an article in Volume VI of the Proceedings of the American Railway Engineering and Maintenance of Way Association******, this formula was afterward changed to $I = S\left(.1 + \frac{220}{L+240}\right)$ because the first formula was thought to give too much impact for long spans. The

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* No. 83.
** No. 126.
*** No. 163.
**** No. 80.
***** No. 42.
****** No. 171.

article also states that Mr. Fred Thompson, bridge engineer of the Southern Railway, discovered that almost identical results were given by the simpler formula $I = S\left(\frac{300}{L + 300}\right)$, and that Mr. Schneider adopted this in the 1895 specifications for the Pencoyd Iron Works.

One-eighth of the gross area of girder webs was to be considered as acting with the flanges to resist bending strains.

Upper chords of trusses were permitted unsupported widths equal to but not greater than 60 times their thicknesses.

The formula used for determining the allowable unit strain in compression members was: $P = \frac{17{,}000}{\left(1 + \frac{L^2}{11{,}000\, r^2}\right)}$.

In the 1904 specifications, members subjected to alternate strains of tension and compression, due to live and dead loads, were proportioned to resist each kind of strain, but the strain was increased by 8/10 of the smaller; and, when live and dead load strains were opposite in character, only 70 per cent of the dead load strain was considered effective in counteracting the live load strain.

Chapter IV

Conclusion

The specifications issued by any one company varied from issue to issue; and for a given year, the various companies used specifications that differed greatly. But in spite of these many variations, the important material in most specifications appears to have been copied from previous specifications, and the number of original investigations seems to have been very small. The following is quoted from an "Historical Sketch of the Development of American Bridge Specifications,"* and applies to the period following 1885:

> Specification writing became a mania, each writer trying to get something a little different from those which he copied, but, as Mr. Onward Bates says, ' While each tried to make an original specification, he never ventured very far from the preceeding ones.'

In an article by A. H. Heller, which appeared in the Engineering News**, November 19, 1903, Mr. Heller made the following statements in referring to his comparison of the requirements of railway bridge specifications:

> No doubt, many engineers will see the desirability of more uniformity in many requirements, but a complete uniform standard for all railway lines would be as impossible as it is undesirable. That there is as much uniformity as there is, is probably due to the fact that few engineers have the time to make original investigations, and therefore follow previous practices and often use, in their specifications, the exact phraseology of some older specifications. There are very few original specifications.

The writer agrees with Mr. Heller in that a complete uniform

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* No. 171.

** See "A Comparison of the Requirements of Recent Railway Bridge Specifications," by A. H. Heller, Engineering News, Vol. 50, No. 21, November 19, 1903.

standard for all railway lines in 1903 would have been undesirable, but that more uniformity in many requirements would have been very advantageous to all concerned.

PART B

BIBLIOGRAPHY

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(Library) indicates that the specification was found in the University Library, either as a booklet or as a part of a book.

(Original) indicates that the specification has been a contribution and can be found in original form. In some cases, the contributions were in the form of photostats (Photostats of Original) or blue prints (Blue Prints of Original). Eventually, film copies will be made of these.

(Film copy) indicates that the specification has been borrowed and filmed, and is available on 35 mm, film.

(Typed) indicates that the specification has been borrowed and typed, and a typewritten copy is available.

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77. 1895 "Specifications for Metallic Bridges," Atchison, Topeka & Santa Fe Railroad. Gift from R. A. Van Ness, Bridge Engineer, Atchison, Topeka & Santa Fe Railway System. (Blue print of Original and Typed)

78. 1895 "Specifications for Iron and Steel Bridges and Viaducts," Guatemala to Central Railroad. Lent by J. R. Lambert, Chief Engineer, Phoenix 1901 Bridge Co. (Typed)

79. 1895 "Notes on Soft Steel for Bridges," by Harry J. Lewis. See Engineering News, Vol. 33, 1895, p. 276-279. (Library and Typed)

80. 1895 "General Specifications for Railroad Bridges," Pencoyd Iron Works, by C. C. Schneider, Chief Engineer. Lent by O. E. Hovey, Consulting Engineer, and J. R. Worcester, Consulting Engineer. (Typed and Film copy)

81. 1895 "Standard Specifications of the Phoenix Bridge Co. for Steel and Iron Railway and Highway Structures." Lent by

J. R. Lambert, Chief Engineer, Phoenix Bridge Co, (Typed and Film Copy)

82. 1895 "Standard Specifications for Iron and Steel Bridges," Union Pacific System. Gift from B. H. Prater, Chief Engineer, Union Pacific Railroad Co. (Photostat of Original)

83. 1896 "General Specifications for Railroad and Highway Bridges, Roofs and Buildings," Baltimore and Ohio Railroad, by J. E. Greiner, Engineer of Bridges. Gift from J. E. Greiner, Consulting Engineer. (Original)

84. 1895 "Specifications for Structural Steel," Baltimore and Ohio Railroad, by J. E. Greiner, Engineer of Bridges. Obtained from P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. This specification is included in No. 83. (Typed and Film copy)

85. 1896 "Standard Specifications for Metal Bridges," Boston and Maine Railroad. Lent by C. T. Morris, Prof. of Civil Engineering, Ohio State University, and a gift from W. F. Cummings, Chief Engineer, Boston and Maine Railroad Co. According to a letter from Mr. Cummings, this is the first printed. specification of the Boston and Main Railroad (Original and Film copy)

86. 1896 "Bridge Specifications," Chesapeake & Ohio Railway Co. Gift from J. B. French, Consulting Engineer. This is the 1892 specification with revisions to 1896. (Original)

87. 1896 "General Specifications for Steel Highway Bridges and Viaducts," New and Revised Edition, by Theodore Cooper, Consulting Engineer. Lent by R. A. Van Ness, Bridge

Engineer, Atchison, Topeka and Santa Fe Railway System. Typed and Film copy)

88. 1895 "General Specifications for Steel Railroad Bridges and Viaducts," New and Revised Edition, by Theodore Cooper, Consulting Engineer. Gift from J. B. French, Consulting Engineer. (Original, Typed, and Filmed copy)

89. 1896 "General Specifications for Railway Bridges," The Osborn Co. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

90. 1896 "General Specifications for Iron and Steel Bridges," Wabash Railroad Co. Gift from J. C. Bousfield, Chief Engineer Wabash Railway Co., lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy and Photostat of Original)

91. 1896 "Specifications for Structural Steel," Wabash Railroad Co. Lent by F. E. Bates, Chief Engineer, Missouri. Pacific Railroad Co. (Film copy)

92. 1896 "Specifications for Structural Wrought Iron," Wabash Railroad Co. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

93. 1897 "Specifications for Iron and Steel Bridges," Chicago and Alton Railroad. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

94. 1897 "Specifications for Iron and Steel Railway Bridges," Chicago, Rock Island and Pacific Railway Co., (Choctaw, Oklahoma & Gulf Railroad Co., and St. Louis, Kansas City & Colorado Railroad Co.) Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

95. 1897 Office Specifications and Moment Table of the Great Northern Railway Company. Gift from H. S. Loeffler, Bridge Engineer, Great Northern Railway Co. (Blue print of Original)

96. 1897 "Specifications for Steel Bridges," also a Stress Sheet made in April, 1896, of the Missouri, Kansas & Texas Railway. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

97. 1897 "Specifications for Iron and Steel Superstructure," Northern Pacific Railroad. Gift from B. Blum, Chief Engineer, Northern Pacific Railway Co. (Blue print of Original)

98. 1897 "Specifications for Railway Bridges," Pennsylvania Lines West of Pittsburgh. Gift from J. E. Greiner, Consulting Engineer. (Original)

99. 1897 "Standard Specifications for Steel Bridges," Pennsylvania Railroad, by Wm. H. Brown, Chief Engineer. Gift from J. B. French, Consulting Engineer, and W. D. Wiggins, Chief Engineer, Pennsylvania Railroad Co. (Original)

100. 1893 "General Specifications for Steel Viaducts and Bridges, Baltimore and Ohio Southwestern Railway Co. Lent by P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Film copy and Typed)

101. 1898 "General Specifications for Railroad Bridges," Buffalo, Rochester, and Pittsburgh Railway Co., by Wm. E. Hoyt, Chief Engineer. Lent by C. T. Morris*. (Film copy)

102. 1898 "Specifications for Bridges and Viaducts of Iron and

Steel, Cincinnati, New Orleans and Texas Pacific (Cincinnati Southern). Lent by C. T. Morris*. (Film copy)

103. 1898 "General Specifications for Railroad Bridges and Viaducts." King Bridge Co. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

104. 1898 "General Specifications for Steel Railway Bridges," Mexican Central Railway Co., Limited, by Lewis Kingman, Chief Engineer. Lent by C. T. Morris*. (Film copy)

105. 1898 to 1901 incl. "Digest of Specification for Steel Railroad and Highway Bridges" by John to C. Trautwine. See 1902 edition and later editions of John C. Trautwine's <u>Civil Engineer's Pocket-book</u>. The specifications digested are dated from 1898 to 1901. (Library and Typed)

106. 1898 "Specifications for Iron and Steel Superstructures," Northern Pacific Railway Co. Gift from B. Blum, Chief Engineer, Northern Pacific Railway Co. (Blue print of Original)

107. 1899 "Specifications for Quality of Material and Workmanship for Wrought Iron and Steel Bridges," Chicago & North Western Railway, by W. H. Finley, Engineer of Bridges. Gift from F. C. Huffman, Asst. Chief Engineer, Chicago & North Western Railway Co., and lent by C. T. Morris*. (Photostat of Original and Film copy)

108. 1899 "Specifications for Wrought Iron and Steel Bridges, Material, Shop Work, Raising, Painting, Inspection," Chicago, St. Paul, Minneapolis & Omaha Railway Co., by Charles W. Johnson, Chief Engineer. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Typed in part)

109. 1899 "Specifications for Steel Railroad Bridges," Delaware, Lackawanna & Western Railroad. Lent by C. T. Morris*. (Film copy)

110. 1899 "General Specifications for Steel and Iron Bridges," to replace all previous issues, Missouri Pacific Railway, by E. Fisher, Engineer of Bridges and Buildings. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railway Co., and lent by C. T. Morris*. (Film copy and Typed)

111. 1899 "General Specifications for the Design of Bridges and Viaducts of Iron and Steel," Northern Pacific Railway Co. Gift from B. Blum, Chief Engineer, Northern Pacific Railway Co. (Blue print of Original)

112. 1899 "Specifications for Wrought Iron and Steel Bridges," Norfolk and Western Railway Co. Lent by C. T. Morris*. (Film copy)

113. 1899 "Specifications for Iron and Steel Bridges," Philadelphia and Reading Railroad Co. The corrections to be applied to the 1893 specifications for the 1899 revision were received by letter from A. E. Owen, Chief Engineer, Central Railroad Company of New Jersey. (Letter, and Photostat of 1893 Original)

114. 1899 "Specifications for Steel Bridges," Union Pacific Railroad. Gift from B. H. Prater, Chief Engineer, Union Pacific Railroad Co., and lent by C. T. Morris*. Include revisions to 1903. (Photostat of Original)

115. 1899 "General Specifications for Steel Bridges," Mountain

State Construction Company, West Virginia Short Line Railroad, by J. B. French, Bridge Engineer. Gift from J. B. French, Consulting Engineer, and lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Original and Film copy)

116. 1900 "General Specifications for Steel Railroad Bridges," American Bridge Co., by C. C. Schneider, Vice-President. Gift from J. B. French, Consulting Engineer, and lent by C. T. Morris, Prof. of Civil Engineering, Ohio State University, I. L. Simmons, Engineer of Bridges and Buildings, Chicago, Rock Island & Pacific Railway Co., and P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Original and Film copy)

117. 1900 "Specifications for Bridges," (Designing,) the Chicago & Alton Railway Co., by H. F. Baldwin, Chief Engineer. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co., and lent by C. T. Morris*. (Film copy)

118. 1900 "Specifications for Bridges," (Material, Shop Work, Raising, Painting, and Inspection,) the Chicago & Alton Railway Co., by H. F. Baldwin, Chief Engineer. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Film copy)

119. 1900 "General Specifications for Railroad and Highway Bridges, Roofs and Buildings," Cleveland, Cincinnati, Chicago & St. Louis Railway Co. Lent by C. T. Morris, and lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Film copy)

120. 1900 "Specifications for Railway Bridges," Cleveland, Lorain & Wheeling Railway Co. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Film copy)

121. 1900 "General Specifications for Bridges," Erie Railroad Co., by C. W. Buchholz, Chief Engineer. Lent by G. S. Fanning, Chief Engineer, Erie Railroad Co. (Film copy)

122. 1900 "Specifications for Material Required for Wrought Iron and Steel Superstructure," Great Northern Railway. Lent by C. T. Morris*. (Film copy)

123. 1900 "Specifications for Steel Bridges," by J. W. Schaub, Consulting Engineer. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

124. 1900 "Standard Specifications for Steel Railway Structures," Southern Pacific Co. Gift from W. H. Kirkbridge, Chief Engineer, Southern Pacific Co. (Photostat of Original)

125. 1901 "General Specifications for Steel Highway Bridges," American Bridge Co., by C. C. Schneider, Vice-President. Gift from J. E. Greiner, Consulting Engineer, and lent by I. L. Simmons, Bridge Engineer, Chicago, Rock Island & Pacific Railway Co. (Original and Typed)

126. 1901 "General Specifications for Railroad and Highway Bridges, Roofs and Steel Buildings," Baltimore and Ohio Railroad Co., by J. E. Greiner, Engineer of Bridges and Buildings. Gift from J. E. Greiner, Consulting Engineer and J. B. French, Consulting Engineer, and lent by C. T. Morris*. (Original)

127. 1901 "General Specifications for Steel and Iron Bridges," Canadian Pacific Railway by P. Alex. Peterson, Chief

Engineer. Lent by C. T. Morris*. (Film copy)

128. 1901 "Specifications for Steel Work, "Chicago Great Western Railway, by A. N. Munster, Bridge Engineer, and F. R. Coates, Chief Engineer. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Typed in part)

129. 1901 "Specifications for Steel Bridges," Chicago, Milwaukee and St. Paul Railway Co., by C. F. Loweth, Engineer of Bridges. Lent by C. T. Morris*. (Typed copy)

130. 1901 "General Specifications for Steel Highway and Electric Railway Bridges and Viaducts," New and Revised Edition, by Theodore Cooper, Consulting Engineer. (Library)

131. 1901 "General Specifications for Steel Railroad Bridges and Viaducts," New and Revised Edition, by Theodore Cooper, Consulting Engineer. (Library)

132. 1901 "General Specifications for Steel Bridges and Viaducts," Department of Railways and Canals, Government Printing Bureau, Ottawa, Canada, by R. C. Douglas, Hydraulic and Bridge Engineer. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Film copy)

133. 1901 "Bridge Specifications," Louisville and Nashville Railroad Co. Lent by C. T. Morris*. (Film copy)

134. 1901 "Specifications for Bridges Carrying Electric Railway," adopted by the Massachusetts Railroad Commission, by George F. Swain, Bridge Engineer. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Film copy)

135. 1901 "Specifications for Steel Bridges," Mobile and Ohio Railroad Co. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Typed in part)

136. 1901 "General Specifications for Railroad Bridges," New York, New Haven and Hartford Railroad Co., by W. H. Moore, Engineer of Bridges. Lent by J. R. Worcester, Consulting Engineer. (Film copy)

137. 1901 "General Specifications for Highway Bridge Superstructures, Osborn Engineering Co. (Library and Typed in part)

138. 1901 "Standard Specifications for Steel Bridges," Pennsylvania Railroad Co., Wm. A. Pratt, Engineer of Bridges, and Wm. H. Brown, Chief Engineer. Gift copy revised to 1905 from W. D. Wiggins, Chief Engineer, Pennsylvania Railroad Co., and gift copy revised to 1906 from J. B. French, Consulting Engineer, and lent by C. Morris*. (Original and Film copy)

139. 1901 "Specifications for Steel Bridges," St. Louis and San Francisco Railroad Co. Lent by C. T. Morris*. (Film copy)

140. 1902 "Specifications for Steel Bridges and Viaducts," Atchison Topeka and Santa Fe Railway System, by A. F Robinson, Bridge Engineer, and James Dun, Chief Engineer. Gift from R. A. Van Ness, Bridge Engineer, Atchison, Topeka & Santa Fe Railway System, and lent by C. T. Morris*. (Original)

141. 1902 "General Specifications for Steel Plate Girders," Chicago and Eastern Illinois Railroad Co. Lent by C. T. Morris*. (Film copy)

142. 1902 "General Description," Chicago and Great Western Rail-

way Co. Lent by C. T. Morris*. (Film copy)

143. 1902 "Specifications for Material and Workmanship," Chicago, Burlington, & Quincy Railroad. This was received by A. H. Heller in 1902, but from photostatic copy of a contract of 1897, it was in use at that time. Gift from G. A. Haggander, Bridge Engineer, Chicago, Burlington, & Quincy Railroad and lent by C. T. Morris, Prof. of Civil Engineering, Ohio State University, from a collection compiled by A. H. Heller. (Original)

144. 1902 Data for Standard Bridges, Chicago, Milwaukee, & St. Paul Railway Co., by C. F. Loweth, according to R. J. Middleton, Asst. Chief Engineer, Chicago, Milwaukee, St. Paul and Pacific Railroad Co. Includes letter of 1904. (Film copy and Typed)

145. 1902 "Specifications for Iron and Steel Railway Bridges," Chicago, Rock Island & Pacific Railway Co. Lent by C. T. Morris*. (Film copy)

146. 1902 "Specifications for Railway Bridges, Loads, Unit-Stresses, Etc.," Chicago, St. Paul, Minneapolis & Omaha Railway Co., by Charles V. Johnson, Chief Engineer. Lent by C. T. Morris*. (Film copy)

147. 1902 "Standard Specifications for Superstructure," Choctaw, Oklahoma & Gulf Railroad Co., F. A. Molitor, Chief Engineer. Lent by I. L. Simmons, Engineer of Bridges, Chicago, Rock Island, & Pacific Railway Co. (Typed in Part)

148. 1902 "Specifications for Foundations and Substructures of Highway and Electric Railway Bridges," by Theodore

Cooper, Consulting Engineer. (Library)

149. 1902 Systems of Loading, Unit Stresses, General Details, Illinois Central Railroad System. Gift from C. C. Westfall, Engineer of Bridges, Illinois Central System. (Photostat of Original)

150. 1902 "Specifications for the Rebuilding of Ten Bridges," International and Great Northern Railroad Co. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Film copy and Typed in part)

151. 1902 "General Specifications for Steel Railroad Bridges," New York Central and Hudson River Railroad Co., Leased and Operated Lines, by O. Hoff, Engineer of Structures, and W. J. Wilgus, Chief Engineer. Lent by J. R. Worcester, Consulting Engineer, G. S. Fanning, Chief Engineer, Erie Railroad Co., and C. T. Morris*. (Film copy)

152. 1902 "General Specifications for the Design of Bridges and Viaducts of Iron and Steel," Northern Pacific Railway Co. Lent by C. T. Morris*. (Film copy)

153. 1902 "Standard Specifications for Steel Railway Structures," Southern Pacific Co., by John D. Isaacs, Engineer of Bridges. Gift from W. H. Kirkbride, Chief Engineer, Southern Pacific Co., and Lent by C. T. Morris*. (Photostat of Original and Film copy)

154. 1902. "Specifications for Bridges, Viaducts and Roof," Southern Railway Co. Lent by C. T. Morris*. (Film copy)

155. 1903 "Specifications for Material and Workmanship for Steel Structures and Schedule of Unit Strain." See <u>Proceed-</u>

ings of the American Railway Engineering and Maintenance of Way Association, Volume IV, p. 130-138, 1903. (Library)

156. 1903 Summary of Compression Formulas - p. 238. Diagram of Formulas, Reduced to 16,000 Base Limit - p. 239. Specification in Table Form Showing: Name; Year; Grade of Steel; Unit Strains, Tension; Unit Strains, Compression; Reduction Formulas of 69 specifications. p. 240-250. See Proceedings of the American Railway Engineering and Maintenance of Way Association, Volume IV. (Library)

157. 1903 Details of Construction, Workmanship, and Material, Buffalo and Susquehanna Railroad Co. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Typed)

158. 1903 "Specifications for Quality of Material and Workmanship for Wrought Iron and Steel Bridges," Chicago and North Western Railway Co., by Wm. C. Armstrong, Bridge Engineer. Gift from F. C. Huffman, Asst. Chief Engineer, Chicago and North Western Railway Co. (Photostat of Original)

159. 1903 "Specifications for Steel Railroad Bridges," Delaware, Lackawanna & Western Railroad Co. Lent by G. S. Fanning Chief Engineer, Erie Railroad Co. (Film copy)

160. 1903 "General Specifications for Railway Bridge Superstructure," Osborn Engineering Co. (Library and Typed)

161. 1903 "Specifications for Material and Workmanship for Iron and Steel Structures," Rock Island System (Chicago, Rock Island & Pacific; Choctaw, Oklahoma & Gulf Railroad Co.; St. Louis, Kansas City & Colorado Railroad Co.). Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad

Co. (Film copy)

162. 1903 "Specifications for Steel Bridges," Union Pacific Railroad Co. Gift from B. H. Prater, Chief Engineer, Union Pacific Railroad Co., and lent by C. T. Morris*. This is a revision to the 1899 specification of the same company. (Photostat of Original) See No. 113.

163. 1904 "Specifications for the Design and Erection of Bridges," Baltimore and Ohio Railroad Co., Baltimore and Ohio Southwestern Railroad. Co., by J. E. Greiner, Engineer of Bridges, Gift from P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co., and J. E. Greiner, Consulting Engineer. (Original)

164. 1904 "Specifications for Material and Workmanship for Steel Structures," Baltimore and Ohio Railroad Co., Baltimore and Ohio Southwestern Railroad Co., by J. E. Greiner, Engineer of Bridge and Buildings. Gift from J. E. Greiner, Consulting Engineer. (Original)

165. 1904 "General Specifications for Steel Railroad Bridges," Delaware and Hudson Railroad Co., by James Mac Martin, Chief Engineer. Lent by G. S. Fanning, Chief Engineer, Erie Railroad. Co. (Film copy)

166. 1904 "General Specifications for Steel Railway Bridges," Lake Shore and Michigan Southern Railway, Leased and Operated Lines, by Samuel Rockwell, Asst. Chief Engineer, and R.H. Reid, General Bridge Foreman. Lent by P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Film copy)

167. 1904 and 1909 Common Standard, SPECIFICATION 1006, Steel and Railway Structures, of Maintenance of Way and Construction. (Original, owned by T. C. Shedd)

168. 1904 "General Specifications for Steel Railroad Bridges and Tables," New York Central and Hudson River Railroad Co. Leased and Operated Lines, by Olaf Hoff, Engineer of Structures, and W. J. Wilgus, Chief Engineer. Lent by G. S. Fanning, Chief Engineer, Erie Railroad Co. (Film copy)

169. 1904 "General Specifications for Steel Bridges, New York, Ontario & Western Railway Co. Lent by G. S. Fanning, Chief Engineer, Erie Railroad Co. (Film copy)

170. 1904 "Specifications for Steel Superstructure of Bridges," Northern Pacific Railway Co. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co. (Film copy)

171. 1905 "Historical Sketch of the Development of American Bridge Specifications." See Proceedings of the American Railway Engineering and Maintenance of Way Association, Volume VI, 1905. (Typed and Library)

172. 1905 Description, General Conditions of Contract, and Specification for Steel Work for bridge 43, Chinese Government Railway. Lent by J. R. Lambert, Chief Engineer, Phoenix Bridge Co. (Typed in part)

173. 1905 Additional Stipulations to the Specification of 1900, Erie Railroad Co. Lent by G. S. Fanning, Chief Engineer, Erie Railroad Co. (Film copy)

174. 1905 "General Specifications for Steel Structures," Long

Island Railroad Co., J. B. French, Bridge Engineer. Gift from J. B. French, Consulting Engineer. (Original)

175. 1905 Letter from Passaic Steel Company by G. H. Blakely, Structural Engineer. Lent by G. S. Fanning, Chief Engineer, Erie Railroad Co. (Film copy) See No. 51.

176. 1905 "Standard Specifications for Steel Bridges," Pennsylvania Railroad Co., Wm. H. Brown, Chief Engineer, and H. R. Leonard, Engineer of Bridges. See No. 138.

177. 1906 "General Specifications for Steel Railroad Bridges - Design." See Proceeding of the American Railway Engineering Association, Volume VII, p. 185-204. (Library)

178. 1905 "Specifications for Steel Bridge Construction, Chicago, Burlington & Quincy Railroad Co. Lent by F. E. Bates, Chief Engineer, Missouri Pacific Railroad Co., also see No. 45. Mr. Haggander, Bridge Engineer, Chicago, Burlington, Quincy Railroad Co. gave this specification the date of 1905 by letter. (Film copy)

179. 1905 "General Specifications for Steel Railroad Bridges and Viaducts," New and Revised Edition, by Theodore Cooper, Consulting Engineer. (Library)

180. 1906 "Specifications for Steel Bridges," First Annual Report of the Illinois Highway Commission, 1906, p. 58-59. (Typed and Library)

181. 1906 "Specifications for Railway Bridges," Pennsylvania Lines West of Pittsburgh. Obtained from P. G. Lang, Jr., Engineer of Bridges, Baltimore & Ohio Railroad Co. (Film copy)

182. 1906 "Standard Specifications for Steel Bridges," Pennsylvania Railroad Co., Wm. H. Brown, Chief Engineer, and H. R. Leonard, Engineer of Bridges. See No. 138

183. 1906 SPECIFICATIONS 1000 for Steel Railroad Bridges, Maintenance of Way and Construction, Rock Island Lines. Gift from I. L. Simmons, Engineer of Bridges, Chicago, Rock Island & Pacific Railway Co., and obtained from P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Original and film copy)

184. 1906 "Specifications for Steel Bridges," South and Western Railway Co. Lent by G. S. Fanning, Chief Engineer, Erie Railroad Co., and P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Film copy)

185. 1906 "Specifications for Steel Railroad Bridges and Structures," Western Maryland Railway Co., H. R Pratt, Chief Engineer. Obtained from P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Film copy)

186. 1908 "General Specifications for Steel Superstructures of Bridges and Viaducts," Department of Railways and Canals, Government Printing Bureau, Ottawa, Canada, 1908. Gift from R. Dorman of the Department of Transport, Ottawa, Canada. (Original)

187. 1908 "Specifications for Bridges Carrying Electric Railways," adopted by the Massachusetts Railroad Commission, by Geo. F. Swain, Consulting Engineer. Lent by J. R. Worcester Consulting Engineer. (Film copy)

188. 1908 "General Specifications for Steel Railroad Bridges,"

New York, New Haven and Hartford Railroad Co., W. H. Moore, Engineer of Bridges. Obtained from P. G. Lang, Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Film Copy)

189. 1908 "General Specifications for Railroad and Highway Bridges, Roofs and Steel Buildings," Seaboard Air Line Railway, E. A. Frink, Bridge Engineer, and W. L. Seddon, Chief Engineer. Gift from W. D. Faucette, Chief Engineer Seaboard Air Line Railway, and obtained from P. G. Lang. Jr., Engineer of Bridges, Baltimore and Ohio Railroad Co. (Original and Film copy)

190. 1909 "General Specifications for Steel Highway and Electric Railway Bridges and Viaducts," New and Revised Edition, by Theodore Cooper, Consulting Engineer, and revised by Bernt Barger. (Library)

191. 1910 "Report of Committee XV- On Iron and Steel Structures," Which is the Revision for the 1906 "General Specifications for Steel Railroad Bridges – Design." See Proceedings of the American Railway Engineering and Maintenance of Way Association, Volume 11, Part I, p. 115-123. (Library)

192. 1911 "Specifications for Steel Bridges," Lehigh Valley Railroad Co., F. E. Schall, Bridge Engineer, and E. B. Ashby, Chief Engineer. Gift from E. J. Cullen, Chief Engineer, Lehigh Valley Railroad Co. (Original)

193. 1911 "General Specifications for Steel Structures," Southern Railway Co. (Original, owned by T. C. Shedd)

194. 1912 "Specifications for Steel Structures, Design, Details of

Construction and Workmanship." See Specifications and Tables for Steel Framed Structures, by the American Bridge Co. (Library and Typed)

195. 1912 "General Specifications for Steel Railroad Bridges," Boston and Maine Railroad Co., A. B. Corthell, Chief Engineer, and B. W. Guppy, Engineer of Structures. Gift from W. F. Cummings, Chief Engineer, Boston and Maine Railroad Co. (Original)

196. 1912 "Specifications for Design and Construction of Steel Railroad Bridges," Chicago, and North Western Railway Co. Gift from F. C. Huffman, Asst. Chief Engineer, Chicago and North Western Railway Co. (Original)

197. 1912 "General Specifications for Steel Railway Bridge Work," Chicago, Milwaukee & St. Paul Railway Co., C. F. Lovett, Chief Engineer. (Original, owned by T. C. Shedd)

198. 1912 "General Specifications for Steel Railroad Bridges," New York, New Haven and Hartford Railroad Co., Edward Cagel, Chief Engineer, and W. H. Moore, Engineer of Bridges. Gift from E. E. Oviatt, Chief Engineer, New York, New Haven and Hartford Railroad Co. (Original)

199. 1912 "Specifications for the Design of Bridges and Subways," by H. B. Seaman. See Transactions of the American Society of Civil Engineers, Volume 75, 1912, p. 311-352. (Library)

200. 1914 "Standard Specifications for Steel Railroad Bridges," Central Railroad Company of New Jersey. Gift from A. E. Owen, Chief Engineer, Central Railroad Company of New Jersey. (Original)

201. 1916 "General Specifications for Fabrication and Erection of

Steel Railroad Bridges," Boston and Maine Railroad Co., A. B. Corthell, Chief Engineer, and B. W. Guppy, Engineer of Structure. Gift from W. F. Cummings, Chief Engineer, Boston and Maine Railroad Co. (Original)

202. 1916 "General Specifications for Steel Bridges," Chesapeake and Ohio Railway Co. (The Chesapeake and Ohio Railway Co. of Indiana). Gift from C. W. Johns, Chief Engineer, Chesapeake and Ohio Railway Co. (Original)

203. 1916 "Standard Specifications for Steel Bridges," Pennsylvania Railroad Co., A. C. Shand, Chief Engineer, H. R. Leonard, Engineer of Bridges and Buildings. (Original, owned by T. C. Shedd)

204. 1916 "General Specifications for Steel Bridges," Virginian Railway Co. Gift from A. M. Traugott, Chief Engineer, Virginian Railway Co. (Original)

205. 1917 "Specifications for Steel Railroad Bridges," New York Central Lines Bridge Engineers' Committee representing the following Railroads: New York Central Railroad; Cleveland, Cincinnati, Chicago and St. Louis Railroad; Michigan Central Railroad; Boston and Albany Railroad; Pittsburgh and Lake Erie Railroad; Toledo and Ohio Central Railway. Gift from B. R. Leffler, Engineer of Bridges, New York Central Railroad Co. (Original)

206. 1920 "General Specifications for Steel Railway Bridges," for fixed spans less than 300 feet in length, American Railway Engineering Association. (Original, owned by T. C. Shedd) See Manual of American Railway Engineering Association, p. 742-779, 1921. (Library)

207. 1920 "General Specifications for Fabrication and Erection of

Steel Structures," Boston and Maine Railroad Co., B. W. Guppy, Engineer of Structures, P. Jones, Bridge Engineer and A. B. Corthell, Chief Engineer. Gift from W. F. Cummings, Chief Engineer, Boston and Maine Railroad Co. (Original)

208. 1920 "General Specifications for Bridge Work," by the Division of Highways, Department of Public Works and Buildings, State of Illinois, Gift from G. F. Burch, Bridge Engineer, Division of Highways. (Original)

209. 1921 "Specifications for Movable Railroad Bridges," New York Central Lines Bridge Engineers' Committee. (Original, owned by T. C. Shedd)

210. 1921 "Standard Specifications for Steel Bridges," Reading Company. Gift from A. E. Owen, Chief Engineer, Central Railroad Company of New Jersey. (Original)

211. 1922 "Specifications for Design and Construction of Steel Railway Bridge Superstructure." Final Report of Special Committee on Specifications for Bridge Design and Construction, American Society of Civil Engineers. See No. 213. (Original)

212. 1922 "General Specifications for Steel Railway Bridges," for fixed spans less than 300 feet in length, Baltimore and Ohio Railroad Co., by P. G. Lang, Jr., Engineer of Bridges. Gift from P. G. Lang, Jr. (Original)

213. 1923 "General Specifications for Steel Railway Bridges," for fixed spans less than 300 feet in length, American Railway Engineering Association. Revised from 1920 copy. See No. 206.

214. 1923 "Specifications for Steel Railway Bridge Superstructure." See Transactions of the American Society of Civil Engineers, Volume 86, p. 476-531. (Library) See No. 210

215. 1923 "Specifications for the Design of Steel Structures," Boston and Maine Railroad Co. Revised from 1920 copy. See No. 207.

216. 1924 "Specifications for Steel Highway Bridge Superstructures." See Transactions of the American Society of Civil Engineers, Volume 87, p.1275-1298. (Library)

217. 1925 "General Specifications for Steel Bridges: Fixed and Movable for Railway or Highway Traffic," M. B. Atkinson, Asst. Superintending Engineer, Welland Canals, St. Catharines, Ontario. Gift from M. B. Atkinson. (Original)

218. 1929 "Specifications for Steel Highway Bridges," Compiled by a conference Committee composed of representatives from the American Association of State Highway Officials and the American Railway Engineering Association. See Bulletin 314 of the A. R. E. A., February, 1929. (Library)

219. 1929 Standard Specifications for Buildings, American Institute of Steel Construction. (Original)

220. 1929 "General Specifications for Steel Railway Bridges," prepared by Committees from the American Society of Civil Engineers and the American Railway Engineering Association. See Volume 55, Part II, p. 2649-2676 of the Proceedings of the American Society of Civil Engineers. (Library)

221. 1929 "Specifications for Design of Bridges Carrying Highway

and Electric Rail Passenger Traffic," The Port of New York Authority, Bridge Department, by O. H. Ammann, Chief Engineer of Bridges. Gift from Edw. W. Stearns, Asst. Chief Engineer, The Port of New York Authority.
(Original)

222. 1931 "Structural Steel Design." See Standard Specifications for Highway Bridges and Incidental Structures, adopted by the American Association of State Highway Officials, published by The Association, Washington, D. C., 1931. (Library)

223. 1931 "General Specifications for Steel Railway Bridges," American Railway Engineering Association. Fourth Edition. (Original, owned by T. C. Shedd)

224. 1933 "General Specifications for Steel Bridges: Fixed and Movable for Railway for Highway Traffic," Department of Railways and Canals, Canada, by M. B. Atkinson, Asst. Superintending Engineer, Welland Canals, St. Catharines, Ontario. Gift from M. B. Atkinson. (Original)

225. 1933 "Standard Specifications B-3001, Steel Railway Bridges for fixed spans less than 300 feet in length," Advisory Committee on Way and Structures, composed of the Chesapeake and Ohio Railway Co., Erie Railroad Co., New York, Chicago and St. Louis Railroad Co., Pere Marquette Railway Co. (Original, owned by T. C. Shedd)

226. 1935 "Specifications for Steel Railway Bridges," for fixed spans not exceeding 400 feet in length, American Railway Engineering Association. (Original)

227. 1938 "Standard Specifications for Movable Highway Bridges," American Association of State Highway Officials. (Library)

PART C

The specifications in the bibliography are listed below under the company name according to the date of publication. The companies are arranged alphabetically by name with the dates of their specifications in a chronological order.

This list was compiled as an index for the bibliography.

Atchison, Topeka and Santa Fe Railway System.
1895
1902

Baltimore and Ohio Railroad Company.
1885
1889
1894
1896 (Design)
1896 (Steel)
1901
1922

Baltimore and Ohio Southwestern Railway Company.
1894
1898

Baltimore and Ohio Railroad Company and Baltimore and Ohio Southwestern Railroad Company.
1904 (Erection)
1904 (Material)

C. H. Blakely.
1889 (Letter concern specifications)

Boston and Maine Railroad.
1896
1912
1916
1920
1923

George Bouscaren, Consulting Engineer.
1887 (Highway)
1887 (Railway)
1890

Buffalo, Rochester, Pittsburgh Railway Company.
1898

Buffalo and Susquehanna Railroad Company.
1903

Canadian and Pacific Railway Company.
    1901

Carnegie Steel Company.
    1893

The Central Railroad Company of New Jersey,
    1914

Chesapeake and Ohio Railway Company.
    1892
    1896
    1916

Chicago and Atchison Railroad Company.
    1873

Chicago and Alton Railroad Company.
    1897
    1900 (Design)
    1900 (Material)

Chicago Bur1inton and Quincy Railway Company.
    1881-1897 (Contracts)
    1887-1906 (Design loads and unit stresses)
    1886
    1902
    1906

Chicago and Eastern Illinois Railroad Company.
    1902

Chicago Great Western.
    1901
    1902

Chicago Milwaukee and St. Paul Railway Company.
    1877
    1888
    1901
    1902
    1912

Chicago and North Western and the Chicago, Milwaukee and St. Paul Railway Companies.
    Undated, held since 1880.

Chicago and North Western Railway Company.
    1899
    1903
    1912

Chicago Rock Island and Pacific Railroad Company.
    1897
    1902

Chicago, St. Paul, Minneapolis, and Omaha Railway Company.
1899
1902

Chinese Government Railways.
1905

Choctaw, Oklahoma, and Gulf Railroad Company.
1902

Cincinnati, New Orleans and Texas Pacific Railway.
1898

Cincinnati Southern Railway Company.
- 1875 (Report of Tests)
- 1875 (Specifications)
- 1880
- 1881

Cleveland, Cincinnati, Chicago, and St. Louis Railway Co.
- 1900

Cleveland, Lorain and Wheeling Railway Company.
- 1894
- 1900

Theodore Cooper.
- 1884 (Class A)
- 1884 (Class B)
- 1884 (Class C)
- 1885
- 1888
- 1890 (Highway)
- 1890 (Railway)
- 1896 (Highway)
- 1896 (Railway)
- 1901 (Highway)
- 1901 (Railway)
- 1902
- 1906
- 1909

Delaware and Hudson Railroad Company.
- 1904

Delaware, Lackawanna and Western Railroad Company.
- 1899
- 1903

Department of Railways and Canals, Canada.
- 1901
- 1908
- 1925
- 1933

A. Jay Dubois.
From book dated 1883.

Erie Railroad Company. (See New York, Lake Erie and Western Railroad Company.)
1874
1900
1905

Great Northern Railway Company.
1897
1900

Guatamala Central Railroad Company.
1895-1901

Illinois Central Railroad System.
1887
1890
1902

Illinois Highway Commission.
1906

State of Illinois Department of Public Works and Buildings.
1920

International and Great Northern Railroad Company.
1902

Keystone Bridge Company.
1887

King Bridge Company.
1898

Lake Shore and Michigan Southern Railway.
1877
1888
1894
1904

Lehigh Valley Railroad Company.
1911

Harry J. Lewis.
1895

Long Island Railroad Company.
1905

Louisville and Nashville Railroad Company.
1901

Maintenance of Way and Construction.
  1904 and 1909

Massachusetts Railroad Commission.
  1901
  1908

Mexican Central Railway Company Limited.
  1898

Missouri Kansas and Texas Railway.
  1897

Missouri Pacific Railway and leased lines.
  1887
  1894
  1899

Mobile and Ohio Railroad Company.
1901

George Morison.
1890-1895 (Used for this period in his Chicago Office)

Nashville, Chattanooga and St. Louis Railway Company.
1893

Nebraska Bridge Company.
1872

New York Central and Hudson River Railroad Company.
1892
1902
1904

New York Central Lines Bridge Committee.
1917
1921

New York and New England Railroad Company.
1892

New York, New Haven and Hartford Railroad Company.
1901
1908
1912

New York, Lake Erie and Western Railroad Company. (See Erie Railroad Company)
1878
1879
1886
1887
1891
1894

New York Ontario and Western Railroad Company.
l904

Northern Pacific Railroad Company.
1883
1897
1898
1899
1902
1904

New York, Pennsylvania and Ohio Railway.
1880

Norfolk and Western Railway Company.
1899

Osborn Engineering Company.
1896
1901
1903

Passaic Steel Company.
1905

Pencoyd Iron Works Bridge and Construction Department.
1887
1895

Pennsylvania Lines--West of Pittsburgh.
1897
1906

Pennsylvania Railroad Standard.
1884
1887
1892
1897
1901 (Revised to 1905)
1905 (Revised from 1901)
1906
1916

Philadelphia and Reading Railroad Company.
1886
1891
1893
1899

Phoenix Bridge Company.
1871
1885
1887
1888
1895

Port of New York Authority--Bridge Department.
1929

Reading Company.
1921

Rock Island System.
1903
1906

Quebec Government Railways.
1880

H. B. Seaman.
1912

St. Louis Bridge Company
1867-1874

St. Louis and San Francisco Railroad Company.
1901

J. W. Schaub.
1900

Seaboard Air Line Railway.
1908

Southern Pacific Railroad Company.
1900
1902

South and Western Railway Company.
1906

Southern Railway Company.
1894
1902
1911

Edwin Thacher, Consulting Engineer.
1893
1894

George H. Thompson, Consulting Engineer.
1894

John C. Trautwine.
1898 to 1901 incl. (A digest of specifications)

Union Pacific Railway Company.
1882
1885
1890 (Material)
1895
1899
1903 (Revisions to 1899)

Virginian Railway Company.
1916

Wabash Railroad Company.
1896 (Steel)
1896 (Iron)

Western Maryland Railway Company.
1906

West Virginia Short Line Railroad Company.
1899

Western Union Railroad Company.
1877

J. M. Wilson
1885