Form Professor Gill ... Mar 21

REPORT

OF THE

JOINT COMMITTEE

CONCERNING THE

ASHTABULA BRIDGE DISASTER,

UNDER

JOINT RESOLUTION OF THE GENERAL ASSEMBLY.

COLUMBUS.
NEVINS & MYERS, STATE PRINTERS.
1877.

REPORT OF THE JOINT COMMITTEE.

On the 12th of January, 1877, the Legislature of Ohio adopted the following joint resolution:

"*Resolved by the General Assembly of the State of Ohio*, That a joint committee be appointed, consisting of five on the part of the House and three on the part of the Senate, to investigate the cause or causes of the recent accident by the giving away of a bridge on the Lake Shore road, at or near Ashtabula, on the evening of Friday, December 29 1876, and which was so disastrous to human life and property, and to inquire whethe any additional legislation is necessary to render travel by rail more secure; and in order that the investigation may be made thorough and complete, it be empowered to employ a short-hand reporter."

The joint committee appointed in pursuance of said resolution beg leave to report:

The bridge was located on the Lake Shore Railroad, near the town of Ashtabula, and over Ashtabula Creek. The chasm spanned by it is about one hundred and fifty feet wide by seventy deep.

Your committee arrived at the scene of the accident January 16th. The purpose of the visit was to procure testimony in relation to the cause or causes producing such fearful consequences, and to enable them the better to understand the testimony which might be brought before the committee.

The bridge went down on the night of the 29th of December, 1876. When your committee arrived, the railroad company had just begun to remove the bridge pieces, and, on consultation, it was thought best, and your committee employed three engineers to take measurements and observations of the work, in company with and under the direction of a sub-committee of their own number. The engineers—Messrs. Benjamin F. Bowen, John Graham, and Thomas H. Johnson—selected by the committee are not connected with any railroad, reside at Columbus, Ohio, away from the line of the railroad on which the accident occurred, and are gentlemen of high standing in their profession.

For a full and accurate description of the structure and its several parts, your committee beg leave to refer to the report, statements, and calculations of said engineers herewith submitted. All of the reports of engineers made to your committee were made under oath. Your committee also took the testimony of Mr. Stone, the President of the Lake Shore Railroad Company at the time of the construction of the bridge, and who was the projector of the bridge; also, of Charles Collins, the engineer in charge of the railroad on that division during the last ten or eleven years, and who took his own life within a few hours after his testimony was taken; Mr. Condon, the master mechanic who constructed, and Mr. Rogers who erected, the structure; and also G. D. Folsom, the locomotive engineer who went down with his engine in the wreck. The coroner's jury, with great courtesy, permitted your committee to examine a part of the testimony taken before it, and we submit of that evidence the statements of engineers A. Gottleib, of the Keystone Bridge Company, and John D. Crehore, of Cleveland, Ohio, and Joseph Tomlinson, who made the original drawings for the bridge. All of the testimony and statements made to the committee are herewith submitted.

From personal observations and calculations, and a patient and careful consideration of all the evidence within reach, your committee arrive at and report the following conclusions:

1. There were from eighty to one hundred lives lost by the failure of the bridge.

2. The bridge went down under an ordinary load by reason of defects in its original construction.

3. The defects in the original construction of the bridge could have been discovered at any time after its erection by careful and analytical inspection, such as the importance of the structure demanded, and thus the sacrifice of life and property prevented.

Among the several defects in the original construction, your committee would mention the following:

The members composing each main brace were so constructed as to act separately, instead of acting as one member, thus reducing the carrying capacity of the metal greatly below what it could have carried in safety if it had been differently disposed. There should have been diagonals riveted to each member of the brace, or other suitable arrangement to unite the members of each brace so that the brace would have formed a truss, and have acted as one member instead of several. No provision was made to prevent lateral buckling or bending of the braces. The longer members were used in compression, and the shorter in tension. If the main braces and counters had been permanently fastened together at their intersection, which they were not, that would have added greatly to the strength of the main brace.

There was the same want of *unity* in the members composing the upper chord as in the main braces. No sufficient provision was made to prevent it from lateral buckling. In fact, at that point in the bridge which first gave way, both the braces and the top chord did buckle laterally. Only a part of the members composing the upper chord received the strain from the braces at each angle block or panel point, and the lugs on the top of the angle blocks, through which the strain was transmitted to the upper chord, it is believed were insufficient for that purpose.

The lateral system between the lower chords was defective in this: the struts were placed at every other panel point, and the tie-rods extended across two panels, and, instead of being fastened at the ends of the struts, were fastened at alternate panel points, crossing each other at the middle of the strut. The sway braces were too small and too infrequent.

The lateral system between the upper chords had the same defects as that between the lower chords, with this exception; the floor-beams had small lugs united to them, and they acted as struts.

No provision was made for holding the members comprising the braces in their places on the angle blocks, and your committee find that many of them were out of place before and at the time the bridge went down. The braces were greatly weakened by imperfect bearings and having their ends chipped off.

A careful calculation showed that the bridge laid down under a load not greater than was liable to be thrown upon it at any time in the ordinary and usual traffic over it. The south truss at the time of the accident supported only 95 per cent. of the weight of the one train on the bridge. The bridge carried a double track. It was so designed, and trains did frequently meet on the bridge. There being but two trusses when trains met, each truss must carry the entire weight of one train; and yet, with only 95 per cent. of the weight of the train on the south truss at the time of the accident, it gave way. A careful and patient calculation of the strength of the brace at the point of failure (third panel point from the west end of the south truss), and of the strain upon it under that load, shows that it had a factor of safety of only one and six-tenths (1.6.), when ordinary prudence and foresight required it to have a factor of safety of five; and the upper chord from the third panel point to the centre of the bridge, numbering from west end, had a factor of safety at the several panel points ranging from two (2) to one and two-tenths (1.2), instead of five.

There was one weight upon the bridge which has been overlooked, and did not enter into the calculation of the engineers, as an inspection of their statements will show, namely, the snow on the bridge at the time of the accident. The proof shows twenty inches of snow on the ground. It is probable that much of the snow had blown off the bridge; but whatever weight of snow or ice there was on the bridge would still further diminish the factor of safety in both the braces and upper chord.

In these calculations no allowance has been made for oscillation, jar, or vibration under a rolling load, but the calculations are made, and the factor of safety arrived at, as if the load was quiescent. The truth is, the bridge was liable to go down at any time during the last ten or eleven years under the loads that might at any time be brought upon it in the ordinary course of the company's business, and it is most remarkable that it did not sooner occur.

It would be needless to say that any engineer would be derelict in his duty who did not provide in the construction of a bridge against wind, snow, ice, and the vibration of a rolling load. They are as much to be anticipated and provided against as the law of gravity.

Your committee are of the opinion that a third or centre truss in bridges carrying two tracks would greatly promote safety and security. The material of the bridge was good, and likewise the workmanship, with the exceptions before stated. There was material enough in the bridge, and a different disposition of it would have secured five times the strength, and small and comparatively inexpensive additions in the way of diagonals on the braces and upper chord, and a securing of the braces to the brace blocks, would have rendered the bridge secure.

It has been suggested that applying the air-brakes while on the bridge, or applying the air-brakes by the second engine while the first engine was using steam, produced such strains upon the bridge as to destroy it. Your committee are of opinion that in the second case the strain would be upon the deck of the bridge, and would not effect the bridge itself. In the first case, while the tendency would be to push the bridge to the west yet the force would chiefly affect the deck; that which would reach the bridge structure would be small; and there was no evidence found at the wreck tending to support such a theory.

The Legislature has no power to punish; it can only, if possible, provide laws which shall render less frequent such frightful calamities as that at Ashtabula, Ohio, and others that might be enumerated. The lesson taught by the failure of a highway bridge at Dixon, Illinois, resulting in the loss of sixty lives, should not go unheeded in Ohio.

In this view of the subject, and as instructed by the resolution, your committee has prepared a bill to regulate the construction and inspection of bridges in Ohio, hereto attached, and made a part of this report. The subject is new in legislation and new to your committee, and we doubt not the bill, though as perfect as we could make it, has still many imperfections, and we invite the scrutiny of the Legislature with a view to its improvement.

There are many and serious difficulties in the way of legislation on the subject. It is impossible to construct a specification in a law that

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will meet all cases that may arise; and then there are some worthy men who expect to remedy the evil of improperly constructed bridges by a higher general education and public sentiment, which shall promulgate, with sufficient force, a correct standard for bridges, rather than by compulsion through legislative action. There is a clashing of interest between bridge companies, between the owners of bridge patents, between engineers as to the best kind and form of structure, and between those who desire to put up permanent and durable work, and a class who can make more money by the erection of cheap and insufficient structures. In the bill your committee have tried to avoid this clashing by providing only for required results, leaving parties in interest to work that out by any design which ingenuity might suggest.

Interested parties will claim that the legislation is in the interest of engineers; but the object sought being to save the lives and property of the people themselves, it is believed this legislation will be sustained by public opinion, notwithstanding the friction that its enforcement may produce.

All the testimony taken before the committee is herewith submitted.

In addition to what has been said of other engineers, in this report, we desire to mention Albert K. Howland, of Boston; W. S. Williams, of Canton, Ohio; Col. Becker, of Pittsburgh; D. W. Caldwell and J. E. Wright, Esqrs., of Columbus, as rendering us efficient and valuable assistance and advice in this investigation.

All of which is respectfully submitted,

A. M. BURNS, *Chairman*,
T. P. BROWN,
Senate Committee.
L. A. BRUNNER,
W. P. WILSTEE,
GEO. L. CONVERSE,
E. A. STONE,
I. M. BARRETT,
House Committee.

A BILL

To secure greater safety for Public Travel over Bridges.

SECTION 1. *Be it enacted by the General Assembly of the State of Ohio*, That all railroad bridges hereafter erected and designed or used for public travel, except those provided for in section seventeen of this act, shall be built to carry, for usual loads, not less than the following, in addition to their own weight, namely: Bridges having a span of seven and a half feet, and under, nine thousand pounds per lineal foot for each track; those having a span of from seven and a half to ten feet, seven thousand and five hundred pounds per lineal foot for each track; those having a span from ten to twelve and a half feet, six thousand and seven hundred pounds per lineal foot for each track; those having a span from twelve and a half to fifteen feet, six thousand pounds per lineal foot for each track; those having a span from fifteen to twenty feet, five thousand pounds per lineal foot for each track; those having a span from twenty to thirty feet, four thousand and three hundred pounds per lineal foot for each track; those having a span from thirty to forty feet, three thousand and seven hundred pounds per lineal foot for each track; those having a span from forty to fifty feet, three thousand and three hundred pounds per lineal foot for each track; those having a span from fifty to seventy-five feet, thirty-two hundred pounds per lineal foot for each track; those having a span from seventy-five to one hundred feet, thirty-one hundred pounds per lineal foot for each track; those having a span from one hundred to one hundred and fifty feet, three thousand pounds per lineal foot for each track; those having a span from one hundred and fifty to two hundred feet, twenty nine hundred pounds per lineal foot for each track; those having a span from two hundred to three hundred feet, twenty-eight hundred pounds per lineal foot for each track; those having a span from three hundred to four hundred feet, twenty-seven hundred pounds per lineal foot for each track; those having a span from four hundred to five hundred feet, twenty-five hundred pounds per lineal foot for each track; and in all bridge trusses of whatever length, the several members in each panel shall be so proportioned as to sustain, in addition to its share of the uniform load as above stated, such concentrated panel load as is herein provided for a bridge of a length equal to the length of the panel.

SEC. 2. Every railroad bridge shall be so constructed as to be capable of carrying on each track, in addition to its own weight, two locomotives coupled together, each weighing ninety-one thousand and two hundred pounds, on drivers, in a space of twelve and a half feet for each locomotive, and said locomotives to be followed by cars weighing twenty-two hundred and fifty pounds per lineal foot, covering the remainder of the span; and all railroad bridges shall be so projected that the loads above mentioned in section one, shall not strain any part of the material in such structure beyond one-fifth its ultimate strength.

SEC. 3. All bridges hereafter erected, and designed or used for public travel, on any highway or wagon road, shall be constructed to carry, besides their own weight, not less than the following standard loads, namely: City and suburban bridges, and those over large rivers, where great concentration of weight is possible, and on highways in manufacturing districts, spans of thirty feet and under, one hundred and ten pounds per square foot: spans from thirty to fifty feet, one hundred pounds per square foot; spans from fifty to seventy-five feet, ninety pounds per square foot; spans from seventy-five to one hundred feet, eighty pounds per square foot; spans from one hundred to two hundred feet, seventy-five pounds per square foot; spans from two hundred to four hundred feet, sixty-five pounds per square foot; on all other highway or road bridges, the standard load shall be not less than one hundred pounds per square foot, in spans of thirty feet and under; ninety pounds per square foot, in spans from thirty to fifty feet; eighty pounds per square foot, in spans from fifty to seventy-five feet; seventy-five pounds per square foot, in spans from seventy-five to one hundred feet; sixty pounds per square foot, in spans from one hundred to two hundred feet; fifty pounds per square foot, in spans from two hundred to four hundred feet. The floor-beam strength for each floor-beam for each wagon-way of city bridges, and those near large manufactories, shall be not less than thirteen thousand and five hundred pounds; for other bridges, not less than eleven thousand, two hundred and fifty pounds.

SEC. 4. In the construction of all bridges for public travel, either for railroads or common wagon ways, the stress on any material used in the construction of the bridge, in carrying the maximum load for which such bridge is designed, shall not exceed the following, namely: For the best quality of wrought iron, in tension, long bars or rods, ten thousand pounds per square inch; for short lengths, eight thousand pounds per square inch, and against shearing force, seven thousand and five hundred pounds per square inch; and for the best quality of wrought iron, in beams either square or cylindrical in section, in compression, the following, namely: Beams having a length of ten diameters, eight thousand one hundred pounds per square inch, with square ends, and seven thousand four hundred pounds with round ends; beams having a length of from ten to fifteen diameters, seven thousand eight hundred pounds per square inch, for square ends, and six thousand and five hundred pounds for round ends; beams from fifteen to twenty diameters, seven thousand four hundred pounds per square inch, for square ends, and five thousand five hundred pounds for round ends; beams from twenty to twenty-five diameters, seven thousand pounds per square inch, for square ends, and four thousand and five hundred pounds for round ends; beams from twenty-five to thirty diameters, six thousand and five hundred pounds per square inch, for square ends, and three thousand eight hundred pounds for round ends; beams from thirty to thirty-five diameters, six thousand pounds per square inch, for square ends, and three thousand two hundred pounds for round ends; beams from thirty-five to forty diameters, five thousand five hundred pounds per square inch, for square ends, and two thousand and seven hundred pounds for round ends; beams from forty to fifty diameters, four thousand and six hundred pounds per square inch, for square ends, and twenty hundred pounds for round ends; beams having a length from fifty to sixty diameters, three thousand eight hundred pounds per square inch, for square ends, and one thousand four pounds for round ends; beams having a length from sixty to seventy diameters, three thousand two hundred pounds per square inch, for square ends, and one thousand one hundred pounds for round ends; and for beams from seventy to eighty diameters, two thousand seven hundred pounds per square inch, for square ends, and nine hundred pounds for round ends. If iron inferior to the best quality be used, either in tension or compression, the stress on the same shall be proportionately less than the foregoing standard for wrought iron of the best quality.

SEC. 5. Cast iron may be used in the construction of bridges, in compression only, and in lengths not exceeding twenty diameters, at the same stresses as those prescribed for wrought iron by this act, and in shapes other than square or cylindrical, whether wrought or cast iron be used, the stresses shall vary accordingly.

SEC. 6. Where wood is used in the construction of any such bridge, as aforesaid, the greatest allowable strains shall not exceed the following, namely: For oak in tension, twelve hundred pounds per square inch; for pine, one thousand pounds per square inch; and in compression, for oak beams of ten diameters, one thousand pounds per square inch; and for pine, nine hundred pounds per square inch; for oak beams, from ten to twenty diameters, eight hundred pounds per square inch, and seven hundred pounds for pine; for oak beams, from twenty to thirty diameters, six hundred pounds per square inch, and five hundred pounds for pine; and in oak beams of from thirty to forty diameters, four hundred pounds per square inch, and three hundred pounds for pine.

SEC. 7. It shall be the duty of all railroad companies or other corporations erecting a bridge for public travel, whether by contract or otherwise, to keep on the spot a competent engineer to superintend the work, who shall have power to reject any piece of material which may have been injured or which may be imperfect from any cause.

Sec. 8. All railroad bridges in this state used for public travel and having over a fifteen foot span, or having a truss, shall be inspected once every month by some competent person appointed by and in the employment of the corporation owning or using the bridge, for the purpose of seeing that all iron posts are in order, and all nuts screwed home, that there are no loose rivets, that iron rails are in line and without wide joints, that the abutments and piers are in good condition, that the track rails are smooth, and that all wooden parts of the structure are sound and in proper condition, and that the bridge is safe and sound in every respect. The person so inspecting railroad bridges shall, as often as once in two months, make report, under oath, giving a detailed statement of the condition of each bridge to the general manager or superintendent of the railroad company employing him, who shall forthwith forward the same to the commissioner of railroads and telegraphs, and such inspection, in whole or in part, shall be made and reported as aforesaid oftener than once in two months, if required by said commissioner, and it shall be the duty of said commissioner to prescribe the form of blanks to be used by such inspectors of railroad bridges, embracing such information as said commissioner may desire.

Sec. 9. All highway bridges for public travel of more than twenty foot space, in or near any city, shall be carefully inspected as often as once in three months, and all other of such bridges having more than twenty foot span as often as once in six months, by some competent and suitable person. For city bridges, the mayor shall appoint the inspector, and the reports shall be made to him, and filed and preserved in his office for public inspection. For county bridges, the county commissioners shall appoint the inspector, and such reports shall be made to the county commissioners and filed and preserved in the auditor's office for the use of the public. For all turnpike bridges, such inspection shall be made by an inspector appointed by the company using the bridge, and report shall be made to the county commissioners of the proper county, and filed and kept as reports on county bridges. All reports shall be made under oath, and the mayor or county commissioners, as the case may be, shall allow the inspector such sum for his services as may be just, which shall be paid in the same manner as claims against the city or county are paid.

Sec. 10. All corporations operating lines of railroad in this state shall, within sixty days from the taking effect of this act, report to the commissioner of railroads and telegraphs, to be preserved in his office, a detailed description of all bridges in this state of more than fifteen foot span, or having a truss, on their respective lines, and used for public travel. Said report shall be under oath, and made by some competent person in the employment of such company, and shall include the name of the stream or obstacle spanned, its location in miles from the nearest prominent point on the road, with the number or other designation of each bridge, the number and length of spans, their strength, the dimensions of all its important members, abutments, and piers, with the kind of material used in the same, and the foundation, and the age of the bridge, and the date when any important changes or repairs were made in the bridge.

Sec. 11. The governor shall, on the nomination of the commissioner of railroads and telegraphs, with the advice and consent of the senate, appoint some competent expert, at a salary not exceeding three thousand dollars a year, who shall have cognizance of the construction and maintenance of every bridge intended for public travel in this state, and who shall hold his office for the period of five years, unless sooner dismissed by order of the governor for reasons affecting his efficiency, in which case such reasons shall be given in writing by the governor, and shall be entered in full upon the public records in his office.

Such expert, before he shall enter upon the discharge of the duties of his office, shall pass a successful examination as to his mathematical and mechanical competency before a committee of three members of the American society of civil engineers, and receive their endorsement in that behalf; and he shall, moreover, take and subscribe the following oath, to be administered by some officer authorized to administer oaths in this state: "I, ————, do solemnly swear that I am not directly or indirectly interested in any railroad or turnpike company, or in any bridge company, or bridge patent, or in the manufacture or sale any bridge materials, and that during my continuance in the office of inspector I will not become so interested, and that I will honestly and faithfully perform, with my best skill and ability, every duty in said office, without fear, favor, or affection, so help me God." Said oath shall be filed and recorded in the office of the governor.

SEC. 12. Said expert shall be subject to the direction of the commissioner of railroads and telegraphs, and all papers, calculations, reports, etc., pertaining to bridges, shall be filed and preserved in the office of said commissioner. It shall be the duty of said commissioner, whenever he is notified, or shall receive information, whether official or otherwise, or shall have reason to suspect that any railroad bridge, or any other important bridge is defective, to immediately cause the same to be inspected by said expert, and if found unsafe, he shall prohibit its use till put in safe condition, and so pronounced by said expert.

SEC. 13. All railroad or turnpike officials having in charge the letting or construction of any bridge of more than fifteen foot span, or having a truss, and all county and state officials having in charge the letting or construction of any highway bridge or bridges of more than thirty-five foot span, shall submit to said expert a strain sheet and drawings of the proposed structure before work has commenced thereon, who shall examine and certify its correctness if correct, and make such alterations as may be necessary, if it be faulty in design, or scanty in materials, according to the standard prescribed in this act; and on the completion of such bridge, said expert shall critically examine the work in all its details, comparing and verifying the sections on the strain sheet with those of the actual structure, and if these last are insufficient, to forbid the use of the work till the bridge is made sufficiently safe and strong. A copy of all plans and strain sheets submitted to said expert, shall be preserved in the office of the commissioner of railroads and telegraphs, and changes made, from time to time, shall be noted on the records or files of said office.

SEC. 14. If said bridge, examined as mentioned in the last section, is up to the standard in all its parts, said expert shall give triplicate certificates to that effect: one to the builder, one to be filed in the office of the commissioner of railroads and telegraphs, and, if a railroad bridge, the third certificate shall be given to the railroad company; if a highway bridge, then a tablet shall be placed on a conspicuous part thereof, containing the third certificate, and also the names of the builders, the name of the officer or officers who accepted the work, the strength of the bridge as designed, and the year of its erection. Any person who shall willfully injure or fraudulently destroy such tablet shall be deemed guilty of a misdemeanor, and, on conviction thereof, shall be imprisoned in the county jail not more than six nor less than three months.

SEC. 15. In all cases there may be an appeal from the decision of said expert to the commissioner of railroads and telegraphs, who shall carefully inquire into the matter in dispute; and any modifications of the orders or decisions of said expert, or changes ordered or made by said commissioner, shall be in writing, and spread upon the records in his office; and if said expert, from press of official business or other cause, shall require assistance, said commissioner may, from time to time, employ such assistance as he may deem proper, and pay for the same out of his contingent fund.

SEC. 16. It shall be the duty of the commissioner of railroads and telegraphs to stop the running of trains on all railroads in this state, where the company or companies operating the same either neglect or refuse to comply with the provisions of this act; and in case of injury to person or property, by reason of defect in any bridge in this state, this act shall not be construed or have the effect to diminish the liability of any corporation or authority, at the time of such injury, using the same. Any person willfully taking a false affidavit, under any of the provisions or requirements of this act, shall, on conviction thereof, be imprisoned in the penitentiary, at hard labor, not more than ten nor less than one year: and any person stealing, concealing or suppressing, or fraudulently destroying any paper, calculation, plan, or other thing, required to be kept in the office of the commissioner of railroads and telegraphs, shall, on conviction thereof, be imprisoned in the penitentiary, at hard labor, not more than three years nor less than one year.

SEC. 17. The standard loads on bridges of narrow gauge railways shall be thirty per cent. less than those provided in the preceding sections of this act. The word "bridge," in this act, shall be held to include trestle-work, each span of trestle being accounted as a separate bridge.

SEC. 18. This act shall take effect and be in force from and after the 10th day of May, 1877.

ENGINEERS' REPORT.

To the Honorable, the Committee of the General Assembly of the State of Ohio:

GENTLEMEN: Pursuant to your order, we proceeded to the scene of the Ashtabula bridge wreck, arriving there on the morning of the 18th of January, 1877, twenty days after the accident. Although considerable time had elapsed between the falling of the bridge and our arrival at the place, yet, in all probability, we could not have been there at a more favorable time to procure the information we sought, to-wit: To take measurements of and note, in detail, the method of construction of the bridge, and the condition and position of the wreck. The debris of the wrecked train had been removed, and workmen were engaged in removing the bridge, some few pieces having been taken out, and large portions raised up in a way quite favorable for examination.

CONSTRUCTION OF THE BRIDGE.

The bridge consisted of two trusses of the Howe-Truss type, executed in iron, and carrying two tracks on the upper chords or deck, and was of the following general dimensions:

Length of span between abutments	150	feet.		
" " " " centers of half blocks	154	"		
" " each panel	11	"		
No. of panels	14	"		
Height from center to center of chords	19	"	8	in.
" " out to out	20	"	0⅝	"
Width in clear between trusses	14	"	0	"
" from out to out of trusses	19	"	6	"

The floor-beams were spaced 3 feet 8 inches, center to center, and consisted of rolled iron I beams, 4 inches x 6 inches, [*d*, plate 1], and were 25 feet 3 inches long, projecting 2 feet 10½ inches over each truss.

The bridge carried two tracks, 4 feet 8½ inch gauge, the outer rails of which were directly over the center of each truss.

The track stringers under the outer rails, consisted of two pieces, 6 inches x 14 inches, and, under the inner rails, three pieces, 6 inches x 14 inches, besides which there were bearing stringers on the outer ends of the floor-beams, each one piece 6 inches x 14 inches, all of white pine.

The deck was 3 inches thick and 26 feet wide, and was laid *close*, covering the entire surface.

Along each side of the floor, was a pine-guard rail, 10 inches x 10 inches, bolted through the deck and bearing-girder to the floor-beams.

Each truss rested on expansion-rollers at the east end, and was constructed as follows:

THE LOWER CHORD.

The lower chord consisted of five members. The outer members of each chord were composed of two pieces, wrought iron bar, 5 inches x $1\frac{3}{8}$ inches, extending throughout the length of the chord. The middle member was one piece, 5 inches x $1\frac{3}{8}$ inches, for a length of three panels from each end, and two pieces for the remainder of its length. The intermediate members were one piece each for four panels from each end, and two pieces for the remainder, all 5 inches x $1\frac{3}{8}$ inches. The resisting material in each panel was, therefore—

First panel, seven pieces, 5x$1\frac{3}{8}$ inches.
Second panel, seven pieces, 5x$1\frac{3}{8}$ inches.
Third panel, seven pieces, 5x$1\frac{3}{8}$ inches.
Fourth panel, eight pieces, 5x$1\frac{3}{8}$ inches.
Fifth panel, ten pieces, 5x$1\frac{3}{8}$ inches.
Sixth panel, ten pieces, 5x$1\frac{3}{8}$ inches.
Seventh panel, ten pieces, 5x$1\frac{3}{8}$ inches.

Each piece was, in general, of the length of four panels, and they were connected after the manner of the splice in a wooden bridge. [See Fig. 1, Pl. 2.] These members were laid flat, with intermediate spaces of 2 inches, making the total width of chord 33 inches. They were secured to the half-blocks in the manner shown in Fig. 2, Pl. 2.

THE UPPER CHORD.

The upper chord was composed of five lines of four by six inches I beams, of varying thickness of web. These beams were of the length of two panels, two and three beams breaking joint alternately, and abutting against lugs cast on the top of the upper angle-blocks (figure 2, plate 3). There was no connection between the angle-blocks and those pieces which passed over continuously, so that the strains transmitted by the braces in each panel would be borne only by those members of the chord which abutted against the lugs on the angle-block. Because of this arrangement, the middle and outer beams of the chord, or, if numbered consecutively, the first, third, and fifth beams sustained all the thrust of of the first, third, fifth, and seventh braces, and the second and fourth beams sustained the thrust of the second, fourth and sixth braces. The second and fourth beams were continuous from the abutments to the second angle-block. The first, third, and fifth beams began at the first angle-block. The thickness of the web was as follows:

First, Third, and Fifth Beams.

From first to third angle-block, $\frac{5}{8}$ inch (*f* plate 1).
From third to fifth angle-block, $\frac{1}{2}$ inch (*e* plate 1).
From fifth to seventh angle-block, 1 inch (*a* plate 1).

Second and Fourth Beams.

From abutment to second angle-block, $\frac{5}{8}$ inch (*d* plate 1).
From second to fourth angle-block, $\frac{1}{2}$ inch (*e* plate 1).
From fourth to center, $\frac{7}{8}$ inch (*b* plate 1).

The beams were spaced laterally three and three-fourth inches apart, between flanges, making the total width of the chord thirty-three inches. At the quarters of each panel there was a five-eighths inch packing bolt passing through the webs, and through cast-iron thimbles, or distance pieces, between the beams.

THE BRACES.

The braces were also of four by six inch I beams of the patterns *c*, *d*, *e*, and *f*. How these different sizes were distributed through the truss we could not determine, as most of them had been displaced in the fall of the bridge, and were among the first parts of the bridge removed from the wreck. It is in evidence before your committee that the braces were not marked in the shop to designate their position in the truss, and that they were placed in position without any regard to the difference in their cross-sections. Their distribution was, therefore, simply a matter of hazard, and the several sizes were intermingled promiscuously.

The number of braces in each panel, as determined from the impressions on the angle-blocks, were:

In first panel, six main braces, five counter braces.
In second panel, six main braces, one counter brace.
In third panel, four main braces, one counter brace.
In fourth panel, four main braces, one counter brace.
In fifth panel, three main braces, two counter braces.
In sixth panel, three main braces, two counter braces.
In seventh panel, two main braces, two counter braces.

They were cut square at the ends, and simply abutted against the faces of the angle-blocks. Most of them had the flanges chipped off at one or more corners where there was interference with the rods. They were placed with the web in the direction of the truss. The faces of the blocks showed that small lugs had originally been cast thereon, to retain the braces in position on the blocks. These lugs were made to fit the brace when placed with its web transversely to the line of the truss, and admitted only four braces on the first and second panels, and to allow the braces to be turned with the web longitudinally, the lugs were all clipped off.

Each angle block showed that a strip two inches wide had been planed off, across the whole length of the block at the middle of each face. Why this was done is not clearly apparent, but its effect was to prevent any bearing on the middle of the web of the braces, and to concentrate all the bearings on the flanges. The number and position of braces provided for in the angle blocks was the same as shown in the original drawing of the bridge, found by your committee in the possession of the coroner at Ashtabula, and a copy of which is herewith presented. This original drawing bears date 1863, and has the signature of J. Tomlinson.

The five counter-braces in each end panel extended from the first lower angle block to the middle of the main braces; and consisted each of a hollow cast-iron strut, $3\frac{5}{8}$ inch external and $2\frac{1}{8}$ inch internal diameter; through which passed a round rod, $1\frac{3}{4}$ inch diameter, tapped into the angle block below, and with a nut on the upper end. The rods passed between the braces, and through cast-iron beveled bearing plates, both above and below the braces, the lower bearing plates receiving the ends of the hollow struts. All other counter-braces were as already described for main braces.

At the intersections of the main and counter-braces there was a rectangular yoke, enclosing all the braces. It consisted of two rods of one inch diameter, passing through end plates, $3x\frac{3}{4}$ inch, and with cast-iron distance pieces in the spaces between flanges of braces, retained in place by their projecting ends, through which the rods passed. These yokes were not secured to the braces in any way to prevent them from sliding up or down the braces with any change of position of the intersection, and could not, therefore, so act as to confine the intersection to any one position. (See figure 3, plate 2.)

Vertical Tie Rods.

The vertical tie rods were eight in number at each panel point, arranged in four pairs, each pair being six inches apart longitudinally, and passing through the angle blocks and the spaces between the chord members. Each rod had a hexagonal head on top, and hexagonal nut at the bottom, and was "upset" at both ends. The heads and nuts bore against strap-washers, five inches by one inch, extending across the chords transversely, each washer receiving four rods. The sizes of rods were as follows:

First panel, eight rods, two and one-eighth inches diameter.

Second panel, eight rods, two inches diameter.

Third panel, eight rods, one and seven-eighth inches diameter.

Fourth panel, four rods, one and seven-eighth inches diameter, and four rods, one and three-fourth inches diameter.

Fifth panel, four rods, one and three-fourth inches diameter, and four rods, one and five eighth inches diameter.

Sixth panel, eight rods, one and five-eighth inches diameter.

Seventh center, eight rods, one and one-half inches diameter.

Angle Blocks.

The angle blocks were of cast iron, and were thirteen inches wide at the base, four inches wide on top, one inch thick at the edge, and three and one-half inches thick at center, with six inch sloping faces. The lower blocks had each a channel three inches wide and one inch deep along the lower surface, which fitted over lugs welded on the upper surface of the chord members. The upper blocks had alternately three and two upright ribs or lugs on the upper surface, against which the top chord members abutted as heretofore explained.

Lateral and Sway Bracing.

The lower system of lateral bracing consisted of diagonal ties, two and one-half inches by one-half inch flat bars, and horizontal struts of ordinary railroad bars. The diagonal ties extended for one panel length at each end, and for two panel lengths throughout the remainder. They were secured by lugs welded on the flat side, fitting into recesses in the under side of the angle blocks, and held in place by the chords.

The struts rested on the projecting ends of the strap-washers, which, in the alternate panels, were four inches longer than the width of chord. There were no means of adjustment, except by making the struts of full length, and forcing them home between the chords. By a singular blunder in the erection of the bridge, the struts, except the first at the west end, were all placed one panel farther west than their true positions, thus placing them at the intermediate panel-points, between the points of attachment of the diagonals.

The upper system was the same as the lower, except that it began and terminated at the first panel-points at each end, and that the floor-beams were made to take the place of the struts by means of lugs riveted to their under surface and abutting against the inner flanges of the upper chords.

Vertical "sway-bracing" was provided at alternate panels (being the same at which the lateral systems were attached). It consisted of one and a quarter round rods, with turn-buckles near the middle of their length. The ends of these rods were flattened to two and a half inches by one-half inch, with square lugs at the extreme ends. They passed between the vertical rods of the trusses, and the lugs were fitted into recesses in the outer ends of the angle-blocks, and held in place by a three-quarter-inch screw-bolt tapped through the sway-rod into the casting.

CONDITION OF THE WRECK.

The first feature which becomes apparent in an examination of the wreck is the fact that the bridge in falling swung to the northward, while the entire deck with the train upon it fell to the southward, and did not fall upon the wreck of the bridge. This indicates that the failure was in the south truss.

The next important feature is the fact that the bridge in falling was drawn to the eastward, about one panel length of the lower chords being turned up against the face of the east abutment. This would indicate that the break occurred at or near the west end, and that the west end reached the ground before the east end had left its seat on the abutment.

This conclusion is further strengthened by a consideration of the manner in which the train was distributed at the bottom of the chasm.

At the time when the break occurred, allowing that the forward engine had passed off the bridge, there could only have been on the bridge, one engine and two express cars, while one baggage-car, one smoking-car, four coaches, and three sleeping-cars, had not yet reached it. Yet, as all but the last two sleeping-cars reached the brink of the chasm, they were deflected to the southward from their forward course, and landed successively nearer and nearer to the east abutment. The last two sleeping-cars, however, were not so deflected, but plunged straight forward into the chasm, and fell upon the wreck of the bridge at the east end.

The inferences from these facts are that the track was not separated at the top of the east abutment until those seven cars had passed that point, but formed an inclined plane, of successively increasing steepness, and which was turned to the southward by the entire deck of the bridge sliding off after the failure of the south truss; and that such separation of the track had taken place when the next to the last sleeping-car reached the brink.

The foregoing considerations point very clearly to the approximate location of the break.

A careful examination of the wreck throughout its entire length, especially with reference to the condition and relative positions of the several parts, developed the following facts [in the following paragraph, where the words "top chords" are used, they must be understood as meaning the "place of the top chord," as indicated by the tops of the rods. The members composing the chords had been generally displaced by the fall, and were removed before our arrival]:

The lower chords were lying straight and nearly parallel throughout their length. The top chords, at the east end. laid to the south of the lower chords, and ran obliquely, crossing the lower chords about four panels from the east abutment; and thence westward to the third panel from the west abutment, they were upon the north side of the bottom chords, maintaining their parallelism throughout this distance. Here their parallelism ceased. The upper chord of the north truss continued to the west end, in the same oblique direction, while that of the south truss was bent sharply around the lugs of the angle-blocks, and at the second panel point was entirely to the south of the lower chord—those pieces which broke joint on these angle blocks, being drawn off the blocks, and those which passed through, being bent around the lugs. From the second to the first panel point, this chord returned northward to the line of the lower chord, and the two shore members were bent around the lugs of the first block. This condition of the wreck is shown by the diagram. [Fig. 3, Pl. 3.]

The first set of braces in the south truss were not bent, but had escaped from their places, and were lying nearly parallel to the face of the abutment, with the lower chord of the north truss resting on them at their upper ends; and the top angle-block, which they had supported, had slipped on the rods to the lower block. The second angle-block had also slipped down the rods to the bottom, and the braces of that panel were bent laterally to the north, until their upper ends nearly approached the lower block, and they were lying in the wreck with their ends but slightly removed from the blocks on which they had abutted, and with the intersection-yoke still around them, though broken. They are also shown in their relative position in the diagram. [Pl. 3, Fig. 3.]

The braces of the third panel were not found by us, but the top block had slipped down the rods to within about four feet of the bottom. The fourth braces were not bent and the top block was not displaced.

These facts show conclusively that the failure occurred in the second and third panels of the south truss; but whether it is to be attributed to the braces or the top chord, or both, requires further consideration, and will be discussed after presenting the calculations of relative strength.

CALCULATIONS.

As a preliminary step in the investigations of strength, we first made a careful estimate of the dead weight of the structure itself. In doing so, we have used the bill of material furnished as part of the testimony of

Amasa Stone, Esq., first comparing the items with our own measurements, and where differences existed, we have followed our measurements and not the bill. The most important disagreement was as to the weights of the rolled I beams, as shown in the statement following:

DIMENSIONS AND WEIGHT OF ROLLED I BEAMS.

Depth.	Width.	Av'g depth of head.	Thickness of web.	Area. Sq. In.	Weight per foot, calculated.	Wt. pr. foot as pr. bill.
6 inches.	4 inches.	$\frac{7}{8}$ inch.	1 inch.	11.25	37.5 pounds.	42 pounds.
6 "	4 "	$\frac{7}{8}$ "	$\frac{7}{8}$ "	10.72	35.7 "	39½ "
6 "	4 "	$\frac{7}{8}$ "	$\frac{3}{4}$ "	10.187	33.93 "	37 "
6 "	4 "	$\frac{7}{8}$ "	$\frac{5}{8}$ "	9.66	32.20 "	34½ "
6 "	4 "	$\frac{7}{8}$ "	$\frac{1}{2}$ "	9.125	30.42 "	32 "
6 "	4 "	$\frac{7}{8}$ "	$\frac{3}{8}$ "	8.594	28.65 "	29½ "

In estimating the weight of the floor-beams and deck, we have taken the length of deck actually resting on the trusses, at 144 feet.

Table I. contains the general dimensions of one truss; table II. contains, in detail, the estimate of the dead-load, and table III. the strains resulting therefrom in the several members of the truss.

Our first calculation of strains resulting from the rolling-load, is based on an assumed uniform load of one ton per foot lineal on each track, which is the load usually assumed by engineers in designing a bridge of this character. This load is what would be produced, in this instance, by a train of three locomotives on each track. This is a load which, ordinarily, will not probably be brought upon a bridge, but which, at the same time, may *possibly* come upon it, and is not largely in excess of the load which would occur with two engines and one loaded express car. It is usually adopted by engineers as the maximum load for which a bridge should be designed, though the more recent practice tends to establish a still higher standard.

The results of this calculation are given below in Table IV.; and the combined strains from dead load and live load, together with the ultimate resisting capacity of the several members, and the "factor of safety," or *ratio* of ultimate resistance to actual strain, are given in Table V.

In computing the ultimate resistance of the compression members, we have used Rankine's Formula; and in applying this formula it is necessary to study carefully the condition of the several members with reference to the efficiency of their end bearings, and their *effective* length as struts.

The top chord members, as heretofore explained, extended over two panels, and abutted against upright lugs on the angle blocks. At the middle of the length, each member would be free to deflect laterally until it came in contact with the adjoining lug. Its farther deflection would depend entirely on the lateral rigidity of the angle block itself. At the points of attachment of the lateral bracing, the angle blocks may be considered as sufficiently fixed in position; but at the intermediate point the block is perfectly free to accompany any lateral deflection which might occur in the chords. We are therefore of the opinion that the top chord members must be considered as of the full length of twenty-one feet and ten inches.

The ends were sawed square, as such beams usually come from the mill. Between the end of each beam and the lug, there was a shim plate of one-fourth inch wrought iron. This plate was inserted to correct an error in the length of the top chord. Its effect on the bearing would be beneficial rather than otherwise, as it would aid to some extent in distributing the pressure more evenly over the surface. Whether these bearings were fully equal to perfectly squared and true bearings, as contemplated in the formula, may be a matter of some doubt; but they would approximate very nearly to such bearings, and in computing the strength of these members, we have so treated them.

The braces were twenty-one feet seven inches long, with a yoke at their intersections, as heretofore described, and as shown more fully at fig. 3, pl. 2. Whether or not this yoke was effective to prevent deflection in the plane of the truss, is immaterial, as the braces were weakest in the lateral direction. That the yoke could have no effect in preventing the entire group of braces from deflecting laterally is clearly apparent; and, aside from all theoretical considerations, there remains the fact that they actually did fail by bending laterally as an entire group, and at the middle of the length of twenty-one feet seven inches.

These bearings were much more imperfect than those of the top chord, owing to the corners of the flanges having been chipped off where they interfered with the rods (see plate 4), and to the uneven surface of the castings against which they abutted; besides which, many of them had slipped on the angle blocks, so that from one-half to the whole of one flange had no bearing at all; and in a few instances, as much as two inches, and even three inches, of the depth of the beam projected over the edge of the blocks.

We are of the opinion that these bearings were somewhat better than rounded ends, but by no means equal to square ends, and we have assumed a mean value between the two.

If the experiments upon the strength of these braces, which were contemplated by your committee, had been carried out, the value to be assigned to the bearings would have become a matter of certainty instead of opinion, and we regret that they were not made, so that the results could have been embodied in this report.

In addition to these calculations, showing the strength of the bridge with reference to the load which it should have been able to sustain, we have also made a calculation of the strains as actually occurring at the time of the failure, and which are also hereto attached.

In this we have assumed that at the time when failure began the forward engine, weighing 32 tons, covered the second and third panels at the west end, the drivers resting equally each side of the third panel point, and was followed successively by its tender, weighing twenty tons and covering 22 feet of track; the second engine, weighing 35 tons, on 32 feet length; its tender, weighing 20 tons, on 22 feet length, and a loaded express car, weighing 23 tons, on 37 feet length. The distance between axles, and the weight on each pair of wheels, was assumed as follows:

ASSUMED DISTRIBUTION OF ROLLING LOAD ON SOUTH TRACK AT THE TIME FAILURE BEGAN.

AXLE.	Distance from preceding axle.	Load on each pair of wheels.
First axle of truck, first engine	0 feet.	11,000
Second " " " "	6 "	11,000
First driving axle, " "	8 "	21,000
Second " " " "	8 "	21,000
First axle of tender, " "	8 "	10,000
Second " " " "	5 "	10,000
Third " " " "	5 "	10,000
Fourth " " " "	5 "	10,000
First " truck, second engine	10 "	12,000
Second " " " "	6 "	12,000
First driving axle, " "	8 "	23,000
Second " " " "	8 "	23,000
First axle of tender, " "	8 "	10,000
Second " " " "	5 "	10,000
Third " " " "	5 "	10,000
Fourth " " " "	5 "	10,000
First " first truck, express car	9 "	11,500
Second " " " "	5 "	11,500
First " second " "	16 "	11,500
Second " " " "	5 "	11,500

The track stringers were placed four feet ten inches from center to center, which placed the center of gravity of the load one foot and a half inch from the point of support of the floor beam; and the clear width between supports being fourteen feet, it follows that 93 per cent. of the load on the south track was borne by the south truss.

In addition to this, according to the records of the United States Signal Service at Cleveland and Erie, at the time of the accident a wind from the north was blowing with a force of about five pounds per square foot.

The surface of an engine exposed to this wind measures about eight feet in height, and its center of gravity is about five feet above the rails. The effect of such a wind against this surface would be to increase the vertical pressure on the south rail about two per cent. of the entire load. The whole load, then, borne by the south truss was about 95 per cent. of the weight of the train, and as such we have computed the strains.

We would add, by way of explanation, that the center lines of braces and counters did not intersect at the center lines of the chords. The horizontal "run" of the braces was ten feet eight inches for a "rise" of nineteen feet eight inches.

Owing to the uncertainty as to the manner in which the different sizes of braces were distributed in the truss, and the certainty that they were used promiscuously, we have used the average value of the ultimate strength of the several sizes. We have reason to believe that the lighter sizes occurred most frequently near the ends, and the heavier sizes near the center. If this was the case, then we have overestimated the strength of the braces near the ends, and underestimated those near the center.

The numbers of the panels in the following tables begin at the west end and number toward the east. [Fig. 1, pl. 3.] Tables I., III., IV., and V. extend only to the center of the truss, the remaining half being symmetrical therewith, with reference to corresponding parts.

TABLE I.—DIMENSIONS OF EACH TRUSS.

	BOTTOM CHORD.		TOP CHORD.		RODS.		MAIN BRACES.		COUNTER BRACES.	
No. panel.	No. pieces.	Size.	No. pieces.	Size.	No. pieces.	Size.	No. pieces.	Size.	No. pieces.	Size.
		Inches.		*4 x 6 I beam. Ins.*		*Inches.*		*Inches.*		*Inches.*
1	7	5 x 1 3/8	2	2 pcs. 5/8 web.	8	2 1/8 round.	6	I beam 4 x 6	5	....
2	7	" "	5	2 " 5/8 " 3 " 3/8 "	8	2 "	6	" "	1	I beam 4 x 6
3	7	" "	5	3 " 3/8 " 2 " 1/2 "	8	1 7/8 "	4	" "	1	" "
4	8	" "	5	2 " 1/2 " 3 " 1/2 "	4 4	1 7/8 " 1 3/4 "	4	" "	1	" "
5	10	" "	5	3 " 1/2 " 2 " 7/8 "	4 4	1 3/4 " 1 5/8 "	3	" "	2	" "
6	10	" "	5	2 " 7/8 " 3 " 1 "	8	1 5/8 "	3	" "	2	" "
7	10	" "	5	3 " 1 " 2 " 7/8 "	8	1 1/2 "	2	" "	2	" "

Span	154 feet.
Height of truss, center to center	19 " 8 inches.
Horizontal run of braces	10 " 8 "
Length of oblique	22.37 feet.
Ratio of oblique to vertical	1.138
" horizontal "	0.543

TABLE II.—Estimated Dead-Weight.

	lbs.	lbs.
Bottom Chord.		
2,768 feet 5 inches x 1⅝ inches	64,433	
162½ " 5 " x 1 "	2,700	
277 " 3½ " x ¾ "	2,423	
		68,556
Top Chord.		
12 I beams 4 inches x 6 inches, web 1 inch, 21 feet 10 inches long	9,825	
12 I " 4 " x 6 " " ⅞ " " " "	9,357	
20 I " 4 " x 6 " " ½ " " " "	13,279	
12 I " 4 " x 6 " " ⅝ " " " "	7,503	
8 I " 4 " x 6 " " ⅝ " 25 feet " "	6,657	
48 packings	1,440	
		48,061
Braces and Counters.		
16 I beams 4 inches x 6 inches, web ¾ inch x 21 feet 7 inches long	11,720	
32 I " 4 " x 6 " " ½ " x " " "	21,007	
86 I " 4 " x 6 " " ⅝ " x " " "	53,170	
10 I " 4 " x 6 " " ⅝ " x " " "	6,946	
20 round tubes 10 feet 3 inches "	4,337	
20 rods 1¾ " 12 " 1 " "	1,957	
24 intersection stirrups	1,392	
Fastenings, etc	600	
		101,129
Main Rods.		
32 round 2⅛ inches x 22 4-10 feet long	8,563	
32 " 2 " x 22 4-10 "	7,505	
48 " 1⅞ " x 22 4-10 "	9,895	
32 " 1¾ " x 22 4-10 "	5,745	
48 " 1⅝ " x 22 4-10 "	7,433	
16 " 1½ " x 22 4-10 "	2,110	
		41,251
Angle-Blocks.		
26 pairs angle-blocks	15,704	
76 washers, 2 feet 9 inches x 5 inches x 1 inch	3,116	
28 " 3 feet 0 " x 5 " x 1 "	1,260	
		20,080
Lateral and Sway Bracing.		
28 sway rods 15 feet long 1¼ inches round	1,718	
12 laterals 28 " 7 inches long, 2½ x ½ inches round	1,429	
12 " 28 " 7 " 2½ x ½ "	1,429	
8 " 21 " 0 " 2½ x ½ "	700	
		5,276

Floor and Upper Structures.

	lbs.	lbs.
39 I beams, 4 inches x 6 inches, web ⅜ inch x 25 feet 3 inches long..	28,927	
84 stirrups	672	
12 wood-stringers, 6 inches x 14 inches x 144 feet 0 inches long	28,224	
Floor, 3 inches x 26 feet 0 inches x 144 feet 0 inches long	26,208	
2 guard-rails, 10 inches x 10 inches x 144 feet 0 inches long	5,600	
4 track-rails, 144 feet	11,520	
Fish-plates and spikes	648	
Packing-bolts and washers	1,316	
		103,115
Total weight of bridge		387,464
Weight per lineal foot		2,516

TABLE III.—STRAINS RESULTING FROM DEAD-LOAD ONLY. WEIGHT PER PANEL, ONE TRUSS, 13,838 POUNDS.

No. panel.	Rods.	Vertical load on braces.	Strain in braces.	Lower chord.	Upper Chord.	
					3 members.	2 members.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	76,109	89,947	102,362	48,841	....	....
2	62,271	76,109	86,614	90,168	48,841	....
3	48,433	62,271	70,866	123,981	....	41,327
4	34,597	48,433	55,118	150,280	82,654	....
5	20,757	34,595	39,370	169,065	....	67,626
6	6,919	20,757	23,622	180,336	101,439	....
7	....	6,919	7,874	184,093	....	78,897

TABLE IV.—STRAINS RESULTING FROM A UNIFORM LIVE LOAD OF TWO THOUSAND POUNDS PER FOOT ON EACH TRUSS.

No. panel.	Rods.	Vertical load on braces.	Strain in braces.	Lower chord.	Upper chord.	
					Three members.	Two members.
1	121,000	143,000	162,734	77,649	....	....
2	99,000	121,000	137,698	143,352	77,649	....
3	77,000	99,000	112,662	197,109	....	65,703
4	55,000	77,000	87,626	238,920	131,406	....
5	33,000	55,000	62,590	268,785	....	107,514
6	11,000	33,000	37,554	286,704	161,271	....
7	....	11,000	12,518	292,677	....	125,433

TABLE IV.—Continued.—MAXIMUM STRAINS FROM PARTIAL LIVE LOADS.

Number panel.	Rods.	Main braces.	Counter braces.
1	121,000	162,734	....
2	103,100	138,660	692
3	86,632	116,513	3,851
4	71,697	96,292	8,666
5	57,993	77,996	15,406
6	45,822	61,626	24,073
7	35,083	47,183	34,665

N. B. The chords receive their maximum strains from *full load* only.

TABLE V.—MAXIMUM STRAINS FROM COMBINED LIVE AND DEAD LOADS, AND THE RESISTING CAPACITY OF THE SEVERAL MEMBERS.

A.—Tension Members.

NUMBER OF PANEL.	LOWER CHORD.				RODS.			
	Strain.	Area.	Strain per square inch.	Factor of safety.	Strain.	Area.	Strain per square inch.	Factor of safety.
	Lbs.	Sq. In.	Lbs.		Lbs.	Sq. In.	Lbs.	
1	126,490	48.13	2,628	21.3	197,109	28.37	6,948	8.1
2	233,520	48.13	4,852	11.5	165,371	25.13	6,580	8.5
3	321,090	48.13	6,671	8.4	135,065	22.08	6,117	9.1
4	389,200	55.00	7,077	7.9	106,292	20.66	5,145	10.9
5	437,850	68.75	6,370	8.8	78,750	17.92	4,394	12.7
6	467,040	68.75	6,793	8.2	52,741	16.60	3,177	17.6
7	476,770	68.75	6,935	8.1	35,083	14.14	2,481	22.6

B.—Compression Members.

Number of Panels.	Upper Chord.				Braces.			
	Strain. Lbs.	No. of pieces.	Ultimate strength. Lbs.	Factor of safety.	Strain. Lbs.	No. of pieces.	Ultimate strength. Lbs.	Factor of safety.
1	....	2	....	......	265,096	6	445,704	1.7
2	126,490	3	316,665	2.5	225,274	6	445,704	2.0
3	107,030	2	216,690	2.0	187,379	4	297,136	1.6
4	214,060	3	325,035	1.5	151,410	4	297,136	1.9
5	175,140	2	233,400	1.3	117,366	3	222,852	1.9
6	262,710	3	358,380	1.4	85,248	3	222,852	2.6
7	204,330	2	233,400	1.1	55,057	2	148,568	2.7

Counter Braces.

Seventh panel—strain, 26,791 pounds; ultimate strength, 148,568 pounds.
Sixth " " 451 " " " 148,568 "

The remaining counter-braces are without strain.

TABLE VI.—STRAINS IN SOUTH TRUSS, FROM 95 PER CENT. OF LOAD, CONSISTING OF TWO ENGINES, ONE EXPRESS CAR, AND A WIND FROM THE NORTH HAVING A FORCE OF FIVE POUNDS PER SQUARE FOOT, AS PREVIOUSLY ASSUMED FOR THE INSTANT OF FAILURE.

(Panels numbered from west to east.)

NUMBER OF PANEL.	Load resting on each panel point.	Rods.	Braces.	Lower Chord.	Upper chord.	
					Three members.	Two members.
1	6,000	119,568	142,555	68,018	....	....
2	25,000	95,818	136,164	132,941	68,018	....
3	24,000	73,018	109,041	184,968	....	64,923
4	24,000	50,218	83,095	224,615	120,045	....
5	20,000	31,218	57,148	251,881	....	104,570
6	17,000	15,068	35,527	268,830	147,311	....
7	28,000	....	17,148	277,009	....	121,519
8	30,000	11,532	13,123	277,009	....	118,349
9	20,000	40,032	45,557	270,745	152,396	....
10	20,000	59,032	67,179	249,007	....	96,611
11	23,000	78,032	88,801	216,950	120,340	....
12	....	99,882	113,666	174,577	....	54,238
13	23,000	99,882	113,666	120,340	66,102	....
14	....	....	138,531	66,102	....	....

The loads on panel points, as given in the second column, are deduced from the distribution of the loads given on page 22.

TABLE VII.—STRAINS FROM LIVE LOAD (TABLE VI.) AND DEAD LOAD (TABLE III.), WITH THE RESISTING CAPACITY OF THE MEMBERS; SHOWING THE ACTUAL CONDITION OF THE TRUSS AT THE APPROXIMATE TIME OF FAILURE.

A.—*Tension Members.*

No. panel.	Lower Chord.				Rods.			
	Strain.	Area.	Strain per sq. inch.	Factor of safety.	Strain.	Area.	Strain per sq. inch.	Factor of safety.
1	116,859	48.13	2,428	23.1	195,677	28.37	6,897	8.1
2	223,109	48.13	4,635	12.1	158,089	25.13	6,290	8.9
3	308,949	48.13	6,419	8.7	121,451	22.08	5,500	10.2
4	374,894	55.00	6,816	8.2	84,813	20.66	4,105	13.6
5	420,945	68.75	6,123	9.1	51,975	17.92	2,900	19.3
6	449,165	68.75	6,533	8.6	21,987	16.60	1,324	42.3
7	461,102	68.75	6,706	8.3	....	14.14	....	....
8	461,102	68.75	6,706	8.3	18,451	16.60	1,112	50.4
9	451,080	68.75	6,560	8.5	60,789	17.92	3,392	16.5
10	418,070	68.75	6,081	9.2	93,627	20.66	4,531	12.4
11	367,230	55.00	6,677	8.4	126,465	22.08	5,727	9.8
12	298,558	48.13	6,203	9.0	162,153	25.13	6,452	8.7
13	210,507	48.13	4,373	12.8	175,991	28.37	6,203	9.0
14	114,943	48.13	2,388	23.4	....	....	....	....

TABLE VII.—Continued

B.—*Compression Members.*

No. panel.	Upper Chord.				Braces.			
	Strain.	No. pieces.	Ultimate strength.	Factor of safety.	Strain.	No. pieces.	Ultimate strength.	Factor of safety.
1	....	2	....	....	244,917	6	445,704	1.9
2	116,860	3	316,665	2.7	222,778	6	445,704	2.0
3	106,250	2	216,690	2.0	179,907	4	297,136	1.6
4	202,699	3	325,035	1.6	138,113	4	297,136	2.1
5	172,196	2	233,400	1.4	96,518	3	222,852	2.3
6	248,750	3	358,380	1.4	59,148	3	222,852	3.8
7	200,415	2	233,400	1.2	25,022	2	148,568	5.9
8	197,250	2	233,400	1.2	20,997	2	148,568	7.1
9	253,835	3	358,380	1.4	69,178	3	222,852	3.2
10	164,237	2	233,400	1.4	106,549	3	222,852	2.0
11	202,994	3	325,035	1.6	143,918	4	297,136	2.0
12	95,565	2	216,690	2.3	184,532	4	297,136	1.6
13	114,943	3	316,665	2.7	200,280	6	445,704	2.2
14	....	2	....	....	240,893	6	445,704	1.8

TABLE VIII.—Compression Strains of Table V. considered with reference to Crushing Strength only.

A.—*Top Chord.*

No. panel.	Strain—lbs.	No. pieces.	Area—sq. in.	Strain per sq. inch—lbs.	Factor of safety.
1	....	2	....	....	....
2	126,490	3	25.78	4,907	7.3
3	107,030	2	18.25	5,865	6.1
4	214,060	3	27.38	7,818	4.6
5	175,140	2	21.44	8,169	4.4
6	262,710	3	33.75	7,784	4.6
7	204,330	2	21.44	9,530	3.8

B.—*Braces.*

No. panel.	Strain—lbs.	No. pieces.	Area—sq. in.	Strain per sq. inch—lbs.	Factor of safety.
1	265,096	6	56.35	4,704	7.6
2	225,274	6	56.35	3,998	9.0
3	187,379	4	37.56	4,990	7.2
4	151,410	4	37.56	4,031	9.0
5	117,366	3	28.17	4,166	8.6
6	85,248	3	28.17	3,026	11.9
7	55,057	2	18.78	2,932	12.3

The factor of safety as given in the foregoing tables is the *ratio* of the working or actual strain to the ultimate strength of the members sustaining the strain. There is some difference in the practice of different engineers as to the value which should be assigned to this factor. The most common practice in bridge building is to require that this factor of safety shall be five, that is to say that the ultimate capacity or breaking limit of strength of each member shall be five times the greatest strain that can possibly come on that member.

CONCLUSIONS.

In the result of these calculations it will be observed—

First. That the factors of safety are extremely irregular, and vary through a wide range.

Second. That all the tension members have very large factors of safety, and were abundantly able to sustain all the strains that could possibly come upon them in this bridge.

Third. That all compression members, except the counter braces, are deficient in capacity, having very small factors of safety.

Fourth. Table VIII shows the factors of safety based on the ultimate *crushing* strength of the metal, without taking into account the tendency to flexure in a long column. Upon this hypothesis the factors of safety are shown to be reasonably large, and correspond more nearly with the factors for the tension members; and it may be that the original calculations were made on this fallacious assumption.

Fifth. Considered with reference to the location of the break, it appears that the weakest point, as to the braces, was in the third panel, and that the weakest point in the top chord was at the center, though the top chord, at the point of failure, does not show a state of security much greater than that of the braces.

The probability is that the braces failed first, and thereby involved the failure of the top chord also. But inasmuch as both members were weak, and both were involved in the break, it is of little importance which member took precedence in the failure. The factors of safety throughout the compression members were so low that failure must have followed sooner or later.

If the several groups of beams composing the braces and top chord had each been combined into a single member, by riveting on to their flanges a system of diagonal plates—say three and a half by half inch—running alternately from right to left and from left to right across the entire group, the bridge would have been abundantly safe. This arrangement would have made each group strongest in the lateral direction and weakest in the direction of the webs of the beams; but in this direction the beams offer about five times the resistance that they do laterally. The top chord members could then only deflect in single panel lengths, and on that account their strength would have been still further increased—twofold. The result would have been that the factors of safety given in the tables would have been increased *five times* for the braces and *ten times* for the chord. They would have been so excessively strong that much of the material might have been omitted.

There were several other defects in this bridge, some of which have been already incidentally alluded to, but which we do not regard as causes of this disaster.

Prominent among these is the error in placing the lateral struts of the lower system at the wrong panel points. The effect of this error was to make both the sway rods and lower laterals almost, if not wholly, inoperative.

Another defect was the absence of any provision for retaining the braces in their places on the angle-blocks. Such provision had been originally made by means of raised lugs on the faces of the blocks at the corners of the flanges of the braces. But in changing the positions of the braces these lugs were removed, and no substitute therefor was provided. This allowed the braces to slip from their places, and make the already imperfect bearings still more defective.

Again, all of the bearings on the angle-blocks should have been planed off to true and even surfaces.

Had the lugs on the upper angle-blocks formed a continuous rib and all the members of the chord been made in single panel lengths, abutting against these ribs, the strains would have been distributed equally to the five members, and the ultimate strength would have been a little more than doubled, because of the shorter length.

We would further add that the material in this bridge, so far as we were able to judge, appeared to be of excellent character, and, excepting the brace bearings, the workmanship was very superior.

Besides the breaks already described there were others of lesser importance, which were evidently the result of the general crash, and not in any way the cause. Among these we may note that many of the sway rods were broken square off in the screw-thread at the turn buckle. This must of necessity have been the case. After the failure of the south truss, the entire weight of that truss would be thrown, with a severe shock, on the sway rods running from the lower south chord to the upper north chord. These rods were seven in number and one and a quarter inches in diameter. It requires no calculation to be able to say that they would snap like pipe stems, and the break would naturally occur at the screw-threads where the rod was weakest.

As to the adaptability of the Howe truss type of bridge for execution in iron, we would say, speaking generally, that any ordinary type of bridge *can* be made abundantly secure, in either iron or wood, if the resisting material is properly proportioned to meet the several strains, and the workmanship is properly executed; and that a failure to provide sufficient materials in any one or more members would be equally fatal in any case. The relative merits of the several types of trusses depend chiefly on questions of economy of construction. The Howe truss type would not be as economical in iron as some others; but if built of proper strength in all its members, would be a good and serviceable bridge.

In conclusion, we would say that we find nothing in this case to justify the popular apprehension that there may be some inherent defect in iron as a material for bridges. The failure was not due to any defective quality in the iron. It was not owing to the sudden effect of intense cold, for failure occurred by bending, and not by breaking. It was not the result of a weakness gradually developed after the erection of the bridge. It was due simply to the fact that it was not constructed in accordance with certain well established engineering principles. We find no evidence of any weakness which could not have been discovered in the plan and avoided in the construction.

Respectfully submitted.

B. F. Bowen,
Thos. H. Johnson,
John Graham,
Civil Engineers.

January 30, 1877.

CLEVELAND, OHIO, *February* 12, 1877.

GEORGE L. CONVERSE, ESQ., *Member General Assembly, Columbus, Ohio:*

In reply to your favor of the 7th inst., I would say that prior to 1852 we had on the Erie Division (between Erie and Cleveland) no engines weighing more than twenty-six tons. We have now eight weighing less than twenty-four tons, and 106 weighing from twenty-four to thirty-six tons, the increase from twenty-six tons being as follows: In 1852, one 27-ton and three 28-ton engines; in 1855, four 30-ton engines; in 1857, two 30-ton engines; 1867, two 30-ton engines; 1869, one 31-ton engine; 1870, three 32-ton engines; 1871, fifteen from 32 to 35 tons; in 1872, thirteen from 34 to 35 tons; in 1873, nine from 35 to 36 tons; in 1874, five 36-ton engines were put upon the road.

Very respectfully yours,

JAMES SEDGLEY,
Gen'l Master Mechanic.

ASHTABULA BRIDGE.

Form	Area	Wt. per Ft.	Value of R^2	Ultimate Strength 21' 7" long		Ultimate Strength 21' 10"	
				Round ends	Square ends	Round ends	Square ends
	sq. in.	lbs					
a.	11.25	37.5	0.7987			39,820 lbs	119,460 lbs
b.	10.12	35.7	0.8265			38,900 "	116,700 "
c.	10.187	33.93	0.8590	38,575 lbs	115,725 lbs		
d.	9.66	32.2	0.8954	37,624, "	112,872 "	37,035 "	111,105 "
e.	9.125	30.42	0.9382	36,670 "	110,010 "	36,115 "	108,345 "
f.	8.594	28.65	0.9872	35,700 "	107,100 "	35,185 "	105,555 "

a, b, d, e & f were used as Top Chord members.

c, d, e & f " " " Braces & Counters.

d " " " Floor Beams

Plate I.

Krebs Lithographing Company, Cincinnati.

ASHTABULA BRIDGE.

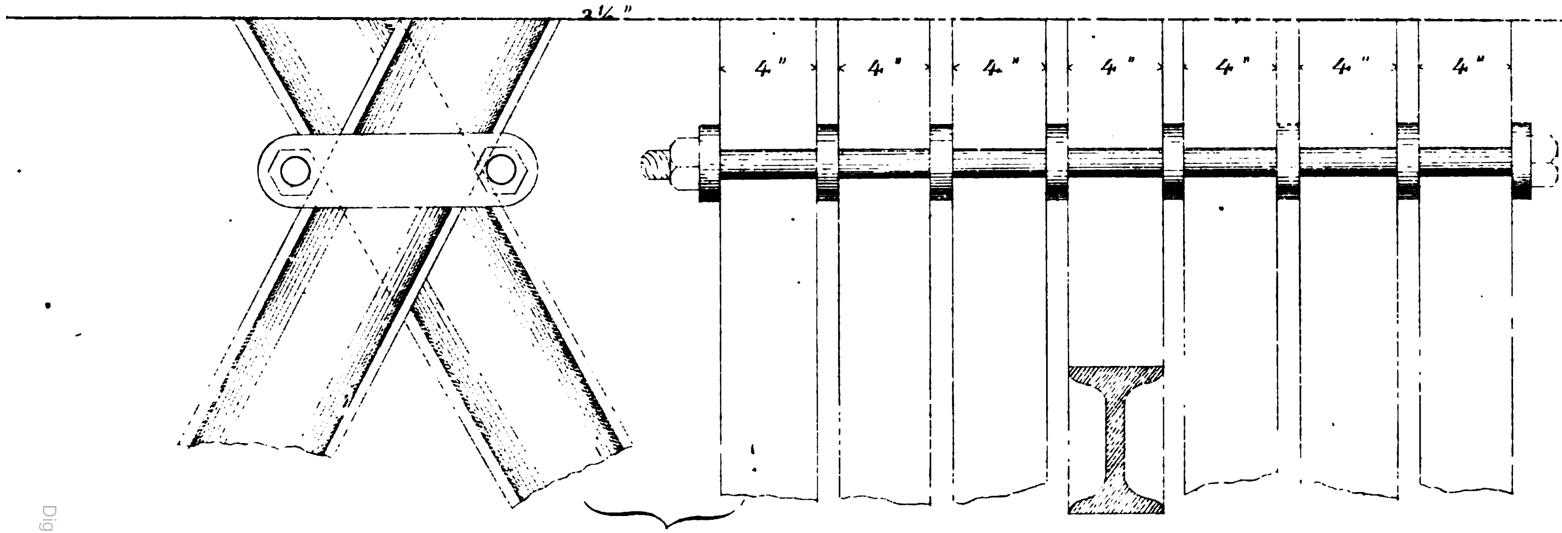


Fig. 3. INTERSECTION YOKE ON BRACES.

Plate II.

Krebs Lithographing Company, Cincinnati.

ASHTABULA BRIDGE.

Fig. 1

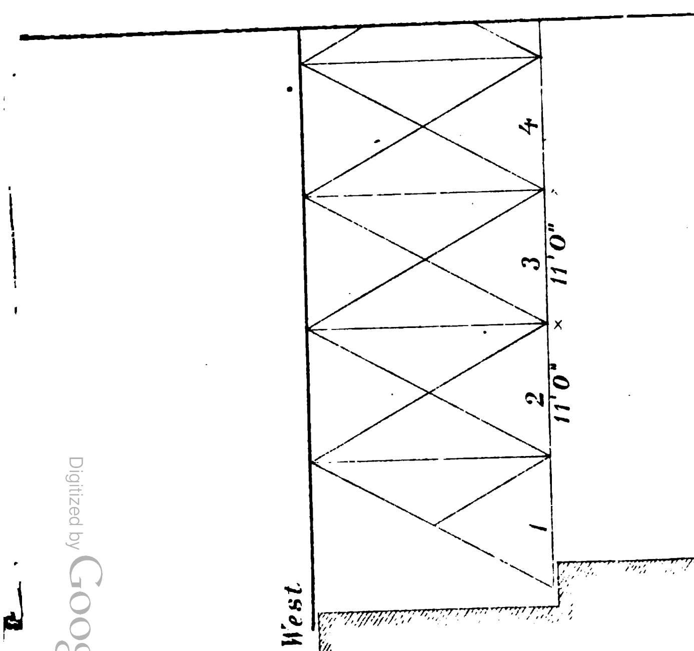


Fig. 2

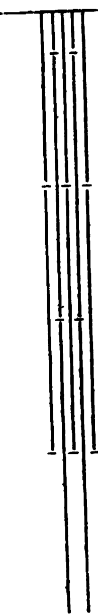


Fig. 3

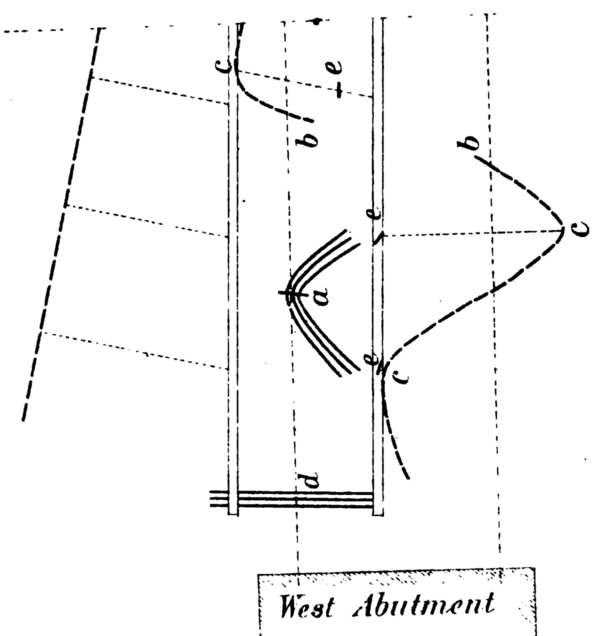


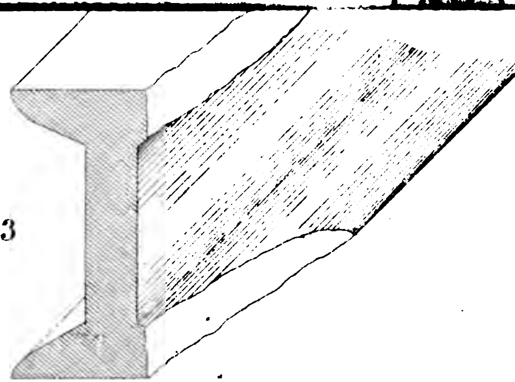
Plate III.

Krebs Lithographing Company, Cincinnati.

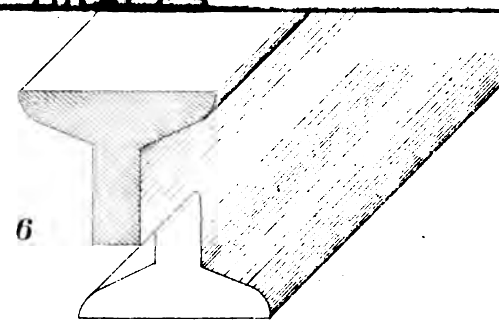
ASHTABULA BRIDGE.

ENDS OF BRACES

3



6



Fig's 1, 2 & 3 occurred frequently.
Fig's 4, 5 & 6 occurred occasionally.

Krebs Lithographing Company, Cincinnati.

Plate IV.

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REPORT OF ALBERT S. HOWLAND.

To the Joint Committee of the Senate and House of Representatives of the State of Ohio:

In the following statement, containing the results of my examinations, which occupied about a fortnight, I give: 1st, a description of the bridge; 2d, my calculations of the strains due to the load at the time of the failure, and the metal to meet them; 3d, my opinion of the defects and cause of failure.

FIRST—DESCRIPTION OF THE BRIDGE.

The point where the bridge spanned the stream is about one thousand feet east of Ashtabula station. On either side of the stream the approach is by a high embankment. From the end of the embankment a viaduct arch reaches to the abutment with a span of about fifty feet.

The abutments appear to be very substantial.. The bridge seats are four by seventeen feet, and the back walls twenty-one feet six inches high and seventeen feet wide, corbeled out three feet on each side near the top. From the water level to the bridge seat is forty-three feet, and to grade, when the bridge was standing, about sixty-six feet. From the bridge seat down, the batter is about two feet. At water level the abutment is twenty-three feet long.

Just south of the abutments and on a line with them are old piers, the east one about forty feet high and the west one about fifteen feet. The intervening space of fifteen feet is occupied by walls about ten feet high catching the foot of the dumps.

There appears to have been no grade in the vicinity of the bridge. To the east the track curves to the right with a radius of about eight thousand feet, the tangent point being at the east abutment. To the west the line is straight. The only original plan of the bridge that I have seen, and the only one in existence, to my knowledge, is that made by Mr. J. Tomlinson. It does not give dimensions, and is on too small a scale to show details well. In several important particulars the plan and structure do not correspond.

The bridge carried two tracks, and consisted of two Howe trusses entirely of wrought iron (except the angle-blocks and some minor details), supporting iron floor beams on which rested wooden track stringers, with a deck of oak plank.

Clear span	150 ft.
Span, out to out of bottom chord	156 ft.
Span between back walls	158 ft.
Distance between trusses, center to center	17 ft. 2 in.
Depth of truss, out to out of angle-blocks	19 ft. 4¼ in.
Depth of truss, center to center of chords	19 ft. 9 in.
Panel length	11 ft.
Gauge of track, center to center of rails	5 ft.
Distance between inner rails, center to center	7 ft. 2 in.

The panel between the east abutment and the first set of vertical rods I designate as panel 1; the next as 2, and so on.

The angle block at the bottom of the first set of vertical rods I call bottom angle block 1; the next to the west 2, and so on.

The angle block at the top of the first set of vertical rods I call top angle block 1; the next 2, and so on.

The braces are distinguished by the number of the panel in which they belong, and also as mains and counters.

The top chord was composed of five lines of 6-inch I beams, spaced about 7¼ inches, centre to centre, each beam reaching two panels. Three feet from each panel point the I beams were connected by a ⅝-inch bolt, with cast spools or distance blocks 1½ inches in diameter at shank, and 2½ inches at ends, and 6 inches long. The ends of the beams are planed.

The top angle blocks were cast with lugs projecting from the top; the lugs are 1⅝ or 1¾ inches thick, 6 inches high, 5 inches wide crosswise of the chord at the top, and 5⅜ to 5⅝ inches wide at bottom. They have planed faces Top angle blocks one and thirteen had lugs 2 inches thick, backed by ribs 2 inches thick. The odd numbered top angle blocks had three lugs, one at each end, and one at center. The even numbered blocks had two lugs. The spaces left between the lugs for the alternate I beams were 8¾ inches. These lugs gave bearings to the different lengths of chord beams, and served to transfer the horizontal thrust of the braces to the chords.

The second and fourth lines of I beams passed through the end angle blocks to recesses 2 or 3 feet wide in the back walls of the abutments, and there took bearing on rollers 20 inches long and 3¼ inches in diameter.

The bottom chord consisted of five lines of bars, each 5x1⅝ inches thick, some being slightly thicker, laid flat, side by side, with spaces for the vertical rods. Each line consisted of two bars, except that the third line dropped the bottom bar in two panels and part of the next panel at each end, and the second and fourth lines dropped the bottom bars in three panels and part of the next at each end. At each panel point a lug 5x3x1 inch was welded to the upper surface of the bars. These lugs fitted a corresponding groove in the bottom angle block. The bars were made in lengths reaching three or four panels. They were spliced by hooks 23 inches long, the shanks being 13x5x1⅜ inches, and the heads 5x5x2⅜ inches. The ends of the bars were carefully shaped to correspond, having heads 5x5x2⅜ inches, the remaining 3 inches of the 13-inch shank being left for a lug welded to the unspliced bar. Over each end of the hook, which was slightly beveled, a band of bar iron 3½x3¾ inches was driven, clamping the hook and the spliced and unspliced bars firmly together. In those panels where the bottom bar of a pair was dropped, a similar device was employed, the end of the bar being forged to a hook shape, and clamped against a lug on the other. At the ends of the truss the bars were shaped as for a splice, the hook being on the upper side, the bottom bars projecting beyond and receiving the upper ones, and these in turn receiving the skew back or half angle block. At the west end the bottom chord rested on several pieces of railroad iron placed transversely; between these rails and the masonry was a piece of ⅜-inch boiler plate. At the east end the bottom chord rested on rollers 34 inches long and 4¼ inches in diameter. There are said to have been five to a truss.

The angle blocks are 33¾ inches long and 15 inches wide at base where they bear against the chord, ¾ inches thick at the edges, and have inclined faces 6¼ inches wide, the apex is truncated, leaving a horizontal surface 4½ inches wide. The holes for the rods are in two lines of four each; the lines are 5¾ inches apart, centre to centre; the spaces between the holes in one line are about 7¼ inches, centre to centre; the bearing face of the block is thus diminished by nearly the area of the holes.

The only projections on the face are lugs (generally in the form of an angle to receive the corner of the braces), one-half inch thick, one-half inch deep, and one and one-half inch long, each way; a large part of them have been entirely, and others partly chipped off. The location of the remaining is suited to receive the end of a brace measuring six inches horizontal, and five inches on the incline. The width of two inches along between the lugs was planed; the rest of the bearing was apparently chipped.

The vertical tie rods are in sets of eight at each panel point; they are round and are upset. Their washers are thirty-three and three quarters inches by five inches by one inch, and take bearing on the I beams of top chord and flat bars of bottom chord.

The braces are six inch I beams, twenty-one feet six inches long, with planed ends, and placed with web in plane of truss. The mains and counters are clasped at their intersection by a yoke composed of two one inch bolts and two washers, two and one-half inches by seven-eighths of an inch; the yokes have cast-iron packing pieces, one-half inch thick, with holes at the ends for the bolts, and projections one inch thick between and near the holes to bear against the flanges of the I beams. Each of the end braces is connected at its centre to the first bottom angle block by three rods, one and three-quarter inch diameter, each rod in a cast-iron tube, two and one-eighth inch and three and five-eighth inch in diameter, the ends of the rods being tapped into the block. In addition, there is a rod on each side of the three, running to a stirrup just under the bottom chord beyond the same angle block. The rods have washers and nuts to clamp the brace.

The track was spiked to a floor or deck of two and three-quarter inch by five inch oak plank, twenty-five and one-half feet long, spaced one and one-half inches; the rails were connected by fish-plates, with two bolts at a joint. The outer rail, directly over the axis of the truss, was carried by a stringer composed of one stick seven by twelve inches, and one stick six by twelve inches; the inner rail by a stringer of one stick seven by twelve inches, and two sticks six by twelve inches. Between and near the rails of each track there were iron guard rails. Along under the ends of the floor plank was a stringer, six by twelve inches, and bolted down to this and the floor beams under it was an oak guard rail, eight and one-half by eight inches, on the plank flooring. There was a pair of these bolts at each end of each floor beam, having a washer seven by two inches by one-half inch, clasping the floor beams; sometimes there was a block of wood between the floor beam and washer. These bolts, so far as I could find out, were the only fastenings between the wooden floor and the iron floor beams. The stringers all rested on iron floor beams of I section, six inches high; the floor beams rested directly on the top chord, and were located at points one foot ten inches and five feet six inches from each panel point; thus there were three floor beams to a panel. There were riveted to the bottom flange of the floor beams along the inner edge of the top chord, pieces of bar iron, four inches by three inches by one-half inch, to hold the trusses apart. Stirrups, passing over the floor beams and down between the outer lines of the top chord I beams, held the floor beams down to the top chord; the stirrups were of bar iron, one and three-quarter inches by three-eighths inch; each took bearing against the bottom of the top chord by two cast-iron washers, five by two and one-fourth inches, having a thickness of one inch, but reduced to five-eighths of an inch at each end, to form shoulders that received the flanges of top chord I beams.

The rolled beams used in the structure for compression members and floor beams are six inches high; the webs from three-eighths to one inch thick; the flanges from four to four and one-fourth inches wide, with a thickness of about one-half inch at the edges, and one and one-eighth to one and three-eighths inches at the intersection of their inclined faces with the axis of the beam.

The area of cross section I make to be eight square inches for three-eighths inch web, and eleven and two-tenth square inches for one inch web.

The floor beams, I find, have a five-eighths inch web.

How the beams of the top chord were arranged with reference to their thickness, I have no means of ascertaining, nearly all having been removed from their position when I first saw the wreck; probably it would have required great pains to determine this at any time since the bridge fell. With the aid, however, of the bill of iron and measurements of a few whose positions I knew, I have made out the probable arrangement, which I give in a table.

In case of the braces the bill of iron gives the thickness of web of the beams and their respective numbers, which correspond with the lugs on the angle blocks. These indications point to the following as the arrangement originally designed. It does not include the beams added when those already in were turned to bring their webs instead of their flanges into the plane of the truss.

Panel.	Main Braces.		Counters.	
	Number.	Web.	Number.	Web.
1	4	$\frac{3}{4}$	....	....
2	4	$\frac{1}{2}$	1	$\frac{3}{8}$
3	4	$\frac{1}{2}$	1	$\frac{3}{8}$
4	4	$\frac{3}{8}$	1	$\frac{3}{8}$
5	3	$\frac{3}{8}$	2	$\frac{3}{8}$
6	3	$\frac{3}{8}$	2	$\frac{3}{8}$
7	3	$\frac{3}{8}$	2	$\frac{3}{8}$

The cross sections of the beams as they were when the bridge was last painted, are in many cases pretty accurately shown by the angle blocks against which the braces bore. I took many measurements of these, noting their location in the trusses. These indications, together with measurements that I was able to take of a few braces whose location in the truss could be inferred from their position, or other circumstances, point to the following conclusions:

1. That but little attention was paid to the thickness of the web in selecting beams for particular panels.

2. That so far as thickness of web was regarded, the heavier beams, with some exceptions, were selected for the central point of the truss.

3. That the beams in the panels each side of the centre, were mostly of about $\frac{3}{4}$ inch web.

4. That the first or end braces had about $\frac{1}{2}$ inch web.

5. That the 86 beams said to be of $\frac{5}{8}$ inch web in bill of iron, were mostly used in bracing the remaining panels, and that their web was rather thicker than $\frac{5}{8}$ inch.

Accordingly, I have assumed for the brace beams, the thickness shown in the table, as the best approximation to the actual arrangement now ascertainable.

The floor beams served for struts in the system of top lateral bracing. The diagonals were $1\frac{1}{4}$ inches round iron flattened to $2\frac{1}{2}$ inches x $\frac{1}{2}$ inch at the end, where a head was formed $2\frac{1}{2}$ inches x 2 inches x 1 inch. The end of the rod fitted a recess in the top of the top angle block, giving a flush surface for the bearing of the top chord on the top angle block. The intersection of the directions of the diagonal rods, is at the outer end of the angle block.

They had turn-buckles for their adjustment, and were not upset. They had a reach of two panels, and had their attachment to the chords at panel points one, three, five, etc., to thirteen; thus there were six pairs of rods.

In the system of bottom lateral bracing, the diagonals were flat bars $2\frac{1}{2}$x$\frac{1}{2}$ inches, with heads $2\frac{1}{2}$x1x$1\frac{3}{4}$ inches, or $1\frac{7}{8}$ inches. They were attached to the chord in the same manner as the top laterals, and at the corresponding panel points. There were also diagonals of the same size for the end panels, reaching to the half-angle-blocks at the abutments. The pair at the west end appear to have been cut for the purpose of lengthening them about $\frac{1}{2}$ inch, and to have been spliced, each, with a short bar of the same section, fastened by a $\frac{5}{8}$ inch bolt at each end of it. None of them were adjustable, so far as I observed. The struts of the system were railroad iron, $4\frac{1}{4}$ inches high, and with a 4 inch base. At certain panel points, the washers at the lower ends of the vertical truss rods projected inward about an inch from the bottom chord; the ends of the struts rested on these projections; holes through the washers and base of the rail received a stirrup, passing over the head of the rail and fastened with nuts under the washers. These struts were located at the following panel points, viz: Two, four, six, eight, ten, twelve and thirteen. Each, therefore, crossed a pair of the diagonals *at their intersection between the chords*, except in case of the strut at thirteen.

The vertical sway-braces were $1\frac{1}{4}$ inches round iron, adjustable by turnbuckles and not upset. The ends, for a length of about 5 inches, were flattened to $2\frac{1}{2}x\frac{1}{2}$ inches, and this part bent to the vertical. At the tip, a hook was formed, $2\frac{1}{2}x1x\frac{1}{2}$ inches. This hook, with a part of the shank, was received by a corresponding recess on the outer end of the angle-block, and held in place by a $\frac{3}{4}$ inch tap-bolt through the shank. When in place, the flat end of the rod was flush with the end of the angle-block.

Second—Strains and Metal to Meet them.

By an approximate estimate, sufficiently close for the calculation of the strains, I make the weight of the structure to be 3,200 pounds per lineal foot of bridge, including the flooring

The average weight of the engines, Socrates and Columbia, which drew the train at the time the bridge fell, is said to have been 110,000 pounds each, including tender, etc., 44,000 of which was on a wheel base of 8 feet. The length I take to have been 52 feet, in accordance with my measurement of an express passenger locomotive in use on the road.

To ascertain with exactness in what ratio the weight of the engine would be distributed, by means of the stringers, floor-beams, and top chords, to the different panel-points beneath it, is, of course, out of the question. I make the assumption, which I think is a close approximation, that the effect of an engine and tender upon the two trusses, was equivalent to a moving load, uniformly distributed, of 1,600 pounds per lineal foot of one track, accompanied by a concentrated load of 27,000 pounds in addition. The express car, with its load, following the engine, would have weighed less per lineal foot than the distributed load assumed for the engines; but, half of its weight being on the forward truck, its effect would have been about the same. With a train on the south track alone, the south truss would have carried about six-sevenths of the train's weight. So I assume that, for the south truss, a train moving on the south track alone, the loads under which the bridge failed were as follows, viz:

Fixed		1,600 pounds per lineal foot.
Moving	Uniformly distributed	1,400 " " " "
	Concentrated, two loads of 23,000 pounds each, five panels apart.	

Top Chord.

Note.—In the table below, I designate the different lines of beams in the top chord by the letters *a*, *b*, *c*, *d*, *e*, from south to north, and any one of the successive beams in either of those lines, by the number of the panel point at the centre of that beam.

Number of panel, or panel point.	Strain—pounds.	Increment of strain at panel points—pounds	Amount of Strain carried by the beams in the lines.		Metal to meet the Strain.			Resulting unit strain on the beams in the respective lines—lbs. per sq. inch.	Safe unit strain for metal as disposed—lbs. per sq. inch.
			a, *c*, and *e*.	*b* and *d*.	No. of I beams.	Thickn'ss of web—inches.	Their section—sq. inch.		
13	136,550	136,550	....	....	......	......	....	....	......
12	251,120	114,570	136,550	....	3	3/8*	24.0	5,700	3,000
11	343,720	92,600	....	114,570	2	1/2	17.2	6,700	3,000
10	414,340	70,620	229,150	....	3	7/8	31.8	7,200	3,000
9	462,980	48,640	....	185,190	2	1/2	17.2	10,800	3,000
8	489,650	26,670	277,790	....	3	1	33.6	8,300	3,000
7	....	....	....	211,860	2	1/2	17.2	12,300	3,000

Bottom Chord.

No. of panel.	Strain—pounds.	Net Section of Metal.			Strain—lbs. per sq. inch.	Safe strain—lbs. per sq. inch.
		Number of bars.	Dimensions—inches.	Area—sq. inches.		
14	136,550	7	5 by 1 3/8	48	2,800	10,000
13	251,120	7	5 by 1 3/8	48	5,200	10,000
12	343,720	7	5 by 1 3/8	48	7,200	10,000
11	414,340	8	5 by 1 3/8	55	7,500	10,000
10	462,980	10	5 by 1 3/8	69	6,700	10,000
9	489,650	10	5 by 1 3/8	69	7,100	10,000
8	506,940	10	5 by 1 3/8	69	7,300	10,000

* I do not think I have seen any top chord I beam so thin as 3/8 inch, given in the bill of iron. The thinnest were about 1/2 inch; with this thickness, the unit strain would be 5,300, instead of 5,700, as given in the table.

VERTICAL TIES.

No. of set.	Strain—lbs.	Net Section of Metal.			Strain—lbs. per sq. inch.	Safe strain—lbs. per sq. inch.
		Number of rods.	Diameter—inches.	Area—sq. inches.		
13	207,240	8	2⅛	28.4	7,300	10,000
12	173,160	8[a]	2	25.1	6,900	10,000
11	140,170	8	2	25.1	5,600	10,000
10	108,290	4[b] 4	2 1⅞	23.6	4,600	10,000
9	77,500	4[c] 4	1¾ 1⅝	17.9	4,300	10,000
8	47,800	8	1⅝	16.6	2,900	10,000
7	20,870	8	1½	14.1	1,500	10,000

a. 8 rods 1⅞ inch in one case.

b. { 4 rods 1⅞ inch / 4 rods 1¾ inch } in one case.

c. { 4 rods 1⅞ inch / 4 rods 1¾ inch } in one case.

MAIN BRACES.

No. of panel.	Strain—lbs.	Section of Metal			Strain—lbs. per sq. inch.	Safe strain—lbs. per sq. inch.
		Number of beams.	Thickness of web—inches.	Area—sq. inches.		
14	277,060	6	½	51.6	5,400	1,000 to 3,000
13	236,850	6	½	51.6	4,600	1,000 to 3,000
12	197,900	4	½	34.4	5,700	1,000 to 3,000
11	160,200	4	½	34.4	4,700	1,000 to 3,000
10	123,760	3	½	25.8	4,800	1,000 to 3,000
9	88,570	3	½	25.8	3,400	1,000 to 3,000
8	54,630	3	⅝	27.9	2,000	1,000 to 3,000
Counter 7	23,850	2	¾	19.8	1,200	1,000 to 3,000

NOTE.—Panels 8, 9, and 10, have two counters each, and 11, 12, and 13, have one counter each.

Lateral and Sway Braces.

The strains to which these systems of bracing might be subjected by the oscillations of a train or other cause are, of course, uncertain. But some idea of the strength that should be provided can be formed by a consideration of the effect of wind pressure. Taking this at 30 pounds per square foot, and the area liable to be exposed to it as 10 feet by 140 feet, we have 21,000 pounds at each end of the bridge to provide for, acting transversely and horizontally. This alone, without including the sway of the train, would require at each end of the bridge about three square inches of metal in each of the three systems of bracing.

Third—Defects.

The most striking defect, and a very serious one, is the style of strut adopted for compression members. The effect of this is seen in the tables above, which show, that while the amount of metal in the compression members was probably in excess of what would have been required if it had been disposed in the most advantageous forms, disposed as it actually was, it was in almost every case strained above the safe limit, and in very many cases to many times that limit.

The members of the top chord are plain I beams, connected twice in an eleven foot panel by bolts and spools which offer no appreciable resistance to the beams bending sideways, parallel to each other; they only require that the beams shall not bend in opposite directions. It may be thought that the floor beams give lateral support to the chord, but the floor beams themselves are about as likely to need support in that direction as the chord is. It is by means of the floor beams that the potential force of the swaying train seeks a resisting point, namely, the abutment; and between the train and the abutment the connections to resist such force should be complete.

The members of the braces also are plain I beams, without a hole for a bolt or rivet, *fastened* to nothing; not connected to each other except at the intersection of the mains and counters by a yoke that could hardly fail to wear loose; depending upon each other for lateral support that neither should be required to give; with nothing to prevent them from bending sidewise parallel to each other. Very slight inequalities in length, such as are indicated by the angle blocks, would give one of the beams a tendency to bend in one direction or the other by the uneven distribution of the strains which would result. The same effect would be produced by the unevenness of the bearing faces of the angle blocks, which were partly chipped instead of planed, a defect in itself. Probably half of the braces had their bearing area reduced by chipping the corners of the flanges where the vertical rods interfered; in many the half of one flange was cut away; I noticed one whose bearing area was reduced to one flange and half the web. Among all the beams of the top chord and braces that I have seen, there has seldom been one that was broken or showed the least sign of a reversed curve.

Another defect is one that appears in many parts of the structure, namely, the dependence of every member for its efficient action upon the probability that all or nearly all the others will retain their positions and do the duty for which they were designed, instead of giving to each member a positive connection with the rest, which nothing but direct rupture will sever. Instead of being made to *hang* together, the members of the structure rested upon one another. This appears in the bearing of the braces on the plane surfaces of angle blocks with nothing but friction to keep them there; in the bearing of members of the top chord against the plane faces of the lugs on the angle blocks with nothing but friction to keep them in their exact places (there was a limit to their possible displacement without rupture by this position between the vertical rods, except in case of the outside line of beams which was held by the clamp bolts passing through the spools); it appears again in the connection of the laterals with the angle blocks, which depends upon the angle blocks and chords always remaining in contact. The bearings of the braces on the angle blocks show displacement in the plane of the truss, varying in amount from half an inch to one and one-half inches in twenty or thirty cases; one beam was half off the angle block. In some cases there was lateral displacement of about one inch.

Another defect is the use of the top chord as a beam to carry the load from the floor beams to the panel points. In a short panel it might not be objectionable to use the chord as a beam, if the chords were deep and the size of the section made, such as to provide for both the direct compression and the compression that results from bending; but these panels were long and the beams were shallow, and had no surplus metal. It would be imposible to tell with any exactness what strain would come upon any member of the chord from this cause, for there is no way of ascertaining how the stringers and floor beams would distribute this weight; but from the results of several calculations, I judge that in this way a single engine would produce more than half the safe strain at the center of a panel, and two-thirds the safe strain at the panel point, and that, too, without making any allowance for the concentration of the weight on the beams at the inner side of the chord, which would obviously increase the strain very much.

Another reason why the use of the top chord to carry the floor beams is objectionable, especially where the lateral braces skip every other panel point, is that the chord is thus made to do duty, again, as a beam in resisting the bending action of the lateral force exerted by the swaying of the train and the wind-pressure upon it. In this way alone a violent wind might strain the chord to about the safe limit.

The whole system of lateral bracing would have been very weak, especially for a deck bridge in an exposed situation, even if it had been constructed as designed. The figures already given show that for wind pressure alone, it should have been two or three times as heavy as it was. But the efficiency of the bottom laterals on which the whole system depends was almost destroyed by the splice with a five-eighth inch bolt at the point where they should have been strongest, namely, in the panel next the abutment; and furthermore, what little virtue there was in the five-eighth inch bolt was rendered almost nil by the peculiar arrangement of the struts between the bottom chords already described. It may be said that the wooden floor assisted by the top chord I beams, that reach from the first angle block to the masonry, had sufficient rigidity to give lateral support to the bridge. To this I would say, that the elasticity of wood and iron are so vastly different that they are not suited to resist conjointly the same force acting upon them in the same manner; the one being very elastic would be likely to yield a good deal before resisting its share of the force, and thus throw the burden upon the other. The top chords, with their laterals and the floor beams, form a rigid rectangle about twenty feet by one hundred and thirty feet; this it might be expected to stay laterally by the wooden stringers with their planking and the top chord I beams mentioned. The stringers, supposing them to be solid sticks, without keys or joints, would be equivvalent to a beam about four feet wide (vertical) by one foot six inches deep (in the direction of the lateral force), and of *one hundred and fifty-eight feet span.* The connections between the rigid rectangle and the floor beams, and between the floor beams and the flexible wooden floor have been already described. How this combination of wood and iron would act in transferring a lateral force to the abutments, would be entirely a matter of conjecture; but, that little should be risked on the chance of its acting harmoniously and efficiently, seems plain. Besides, the connection between the stringers and the abutments is not likely to have been such as should be relied upon to resist much lateral force, applied suddenly, perhaps, and attended with vibrations. In this connection, it is worth noting that if the bridge depended on the wooden floor and the projecting top chord I beams for lateral support, the yielding of the wood may have caused the I beams to act as a lever on the chord, tending to throw it out of line at the angle block next to the end.

Respecting the quality of the metal, little need be said at present, pending the tests that are proposed, but it seems to have been good. Only a few of the tension members gave way, and some of the compression members came out bent nearly double to a sharp curve, without sign of fracture at the edge of the flanges, the paint being still on.

Before giving my opinion of the cause of the failure, I will describe briefly the location and appearance of some portions of the ruins, and some marks on the masonry. When I arrived at the scene of the wreck, the debris and most of the compression members had been removed. Some of the trestles used in erecting the new bridge were still in place. When these were removed and the ice cut away, the south bottom chord, I observed, was lying nearly along the axis of the bridge, slightly convex to the south, but otherwise quite straight. The north bottom chord was in just about its normal position relative to the south chord. Both had moved about eight feet east and eight feet north in the fall. At the first panel point they were crowded down close to the abutment, the ends mostly sticking up. Just west of panel point twelve, south truss, two of the inner bars of the bottom chord were broken. At the ends the bottom chords were generally straight, except that at the east end of the south truss they were bent, say 10° or 20°, convex up, at three or four feet from the end.

The beams of the south west end brace fell together, the upper ends being *under* the end of the north bottom chord. They were nearly straight except as bent by the chord. The sets of vertical ties were generally held together by the angle-blocks and washers, and fell as follows, viz: thirteen of south truss were spread out fan-shaped toward the west with their heads against the abutment, and the angle-block crushed down to the bottom chord; twelve south fell to the south, its angle-block down; eleven south fell to the north, and *under* the north bottom chord. The rest fell north, except a few sets of each truss at the east end.

The south corners of the west abutment received a severe blow three or four feet below grade, breaking off a cubic yard or so of masonry. The west end of the south bottom chord broke off the face of the stone beneath it. One or more of the southeast end braces struck against the back wall about one foot above the bridge seat, and two feet six inches north of the center line of the truss. The faces of the abutments show but few scratches. The lower ends of the first set of vertical rods of the south truss scraped the masonry for a few feet near the bottom.

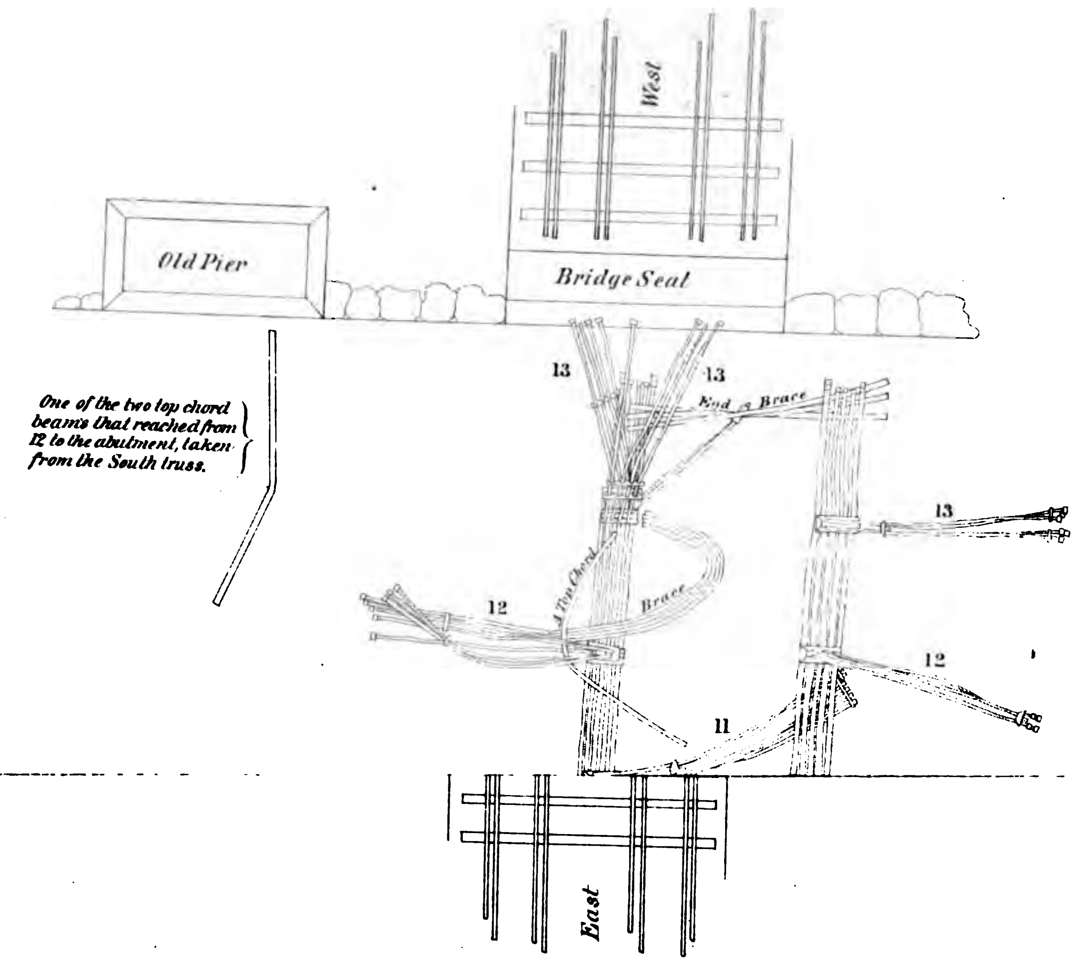
The second engine, the Columbia, is said to have fallen, bottom up, head east, on the west end of the first express car, south of the bridge and near the west abutment, and nearly all the rest of the train to have fallen on the south side of the bridge.

I think that the failure began in the top chord of the south truss at the twelfth angle-block, that is, at the second set of vertical rods counting from west to east; that it probably resulted from the buckling outward of the three I beams which are continuous at that point, under the combination of these forces, viz: first, the thrust due to their position in the truss; second, the vertical bending action of the load from the floor beams when the drivers were perhaps astride the panel point, this bending action being most severe upon the inner of the three top chord I beams, on account of the deflection of the floor beams; and third, the horizontal bending action due to the swaying of the train (the effect of which would be most severe at the west abutment), to the pressure of the wind, perhaps, and to the deflection of the loaded truss, an influence that always operates in the same direction.

The movement of the bridge to the north and east, as it fell, seems to me very natural from a consideration of the motions that might result if a heavy weight were dropped on a smooth wedge pointed toward the south and west. The traction of the engine when the air brake was applied doubtless produced part of the effect.

The position of the southwest end braces, and the eleventh set of vertical ties *under* the north bottom chord, shows that the failure began in this immediate vicinity; the relative position of train, bridge, and abutment after the fall, and other circumstances, are in harmony with this view. If the failure had been started by the breaking of a lateral or vertical sway brace, the end brace and the vertical ties at twelve and eleven, would not have been likely to fall alternately north, south, and north. If a set of braces had been the first to fail by buckling or displacement, the washers at the top of the eleventh or twelfth set of vertical rods would have been bent or distorted, but they were in almost perfect condition when removed from the wreck, being only a slight bend at the end.

In case of derailment of an engine, the forty-four hundred pounds on the four drivers, falling all at once from the top of the rail to the oak planking, would be able to perform about sixteen thousand pounds of mechanical work in deflecting one truss. If the truss had been accurately proportioned in all its members and connections for a total load of four thousand pounds per lineal foot, and a unit strain of eight thousand pounds for parts in tension and corresponding unit strains for those in compression, the deflection due to this load would have been about eight


Old Pier
Bridge Seat
West
13
13
End of Brace
One of the two top chord beams that reached from 12 to the abutment, taken from the South truss.
A Top Chord
Brace
12
13
12
11
East

one-hundredths of a foot, and the work done in producing it, by a load acting at the center of the span, would have been about eleven thousand foot-pounds.

From this I conclude that the fall of the four drivers at the same time from the top of the rail to the floor at the center of the span, while the bridge was supporting the rest of its load also, would not have strained the structure to more than about one-third or one-half its ultimate strength, if all parts had been proportioned in accordance with the unit strain of eight thousand pounds for parts in tension, and the unit strain for parts in compression had been so adjusted to their particular shapes as to give them the same strength as the parts in tension.

In view of the appalling nature of this disaster, it seems fitting to state here that I think there is urgent need of thorough and complete experiments on the forms and qualities of iron now used in important structures, especially for members subject to compression, such experiments as have already been inaugurated with the encouragement, to some extent, of the National government.

All of whioh is respectfully submitted.

ALBERT H. HOWLAND,
Civil Engineer.

BOSTON, MASS., Feb. 12, 1877.

REPORT OF W. S. WILLIAMS.

* * * The iron in the bridge seems to have been of the best quality, and apparently not deteriorated any by use. It shows very little crystalline, or, more properiy speaking, no granular structure. The I beams are laminated, showing that when the iron was placed in the pile to be rolled there was a layer of cold, short iron to give stiffness and resist compression; and a layer of red, short iron to give the fibrous ductile quality, and so on throughout the entire beam.

Very few frost brakes were perceptible in the entire wreck, and in fact very few fractures of any kind were seen. All of the forging throughout the entire bridge was well done, and showed excellent workmanship.

Upon an analytical examination of the general pean of the bridge, it does not show an economical distribution of the iron. In each panel, the lower chord as base, the truss vertical rods as perpendicular, then the braces would form the hypothenuse of a right angled triangle. Then as iron stands a much greater strain in tension than it does in compression, or, in other words, to increase the length of a member in tension does not weaken it; but just the reverse is true of a member in compression. Therefore, we have in this case the braces as the hypothenuse, which is the largest side. But at the same time it must be recollected that at the time of the construction of this bridge there was comparatively little known about pin couplings, and there have been great improvements made within the last eleven years in the construction and in the general plan and details of iron bridges.

As to the amount of material in this bridge, the lower chords and the vertical rods show a large excess. The upper chords show somewhat of a deficiency; while the weakest point as to the amount of material, seems to be in the braces in the third and fourth panels from the abutments, the fourth set of braces showing a factor of safety of two and one-half.

The lateral bracing in this bridge was very deficient, for the following reasons: The vibratory and bottom laterals were attached to the trusses at points where there were no streets, the streets being at points where the lateral rods crossed each other, with the exception of one at the west abutment that was in its proper position.

As to the appearance of the wreck, the whole bridge seems to have been thrown to the north-east, with the lower chord, of about one panel length, doubled up against the east abutment.

It appeared that the third and fourth set of braces in the south truss, near the west abutment, was bent laterally, and was thrown about promiscuously. The second set from the west abutment was buckled as a set complete, with the yoke about them entire and unbroken. The first set at the west abutment had fallen under the lower chord of the north truss, and no bind in them except where this chord had fallen upon them. As to the vertical truss rods in the south truss, near the west abutment, the first, second, and third cast-iron tap block had fallen down on the rods, and were resting against the lower cast-iron brace blocks. The rods above these brace blocks were twisted and bent. Two sets of these rods had fallen under the lower chord of the north truss.

As to the probable cause of this bridge giving away, it would seem that from the length of time it has been in use, and by referring to the strain-sheet, hereto attached, it would appear that there must have been some unusual and extraordinary cause, or combination of causes, that would have produced this result.

From the manner this bridge was braced laterally, in case a vibration was produced from any cause whatever, it would not be taken up by the streets and rods and neutralized, but would be carried along the entire truss, increasing in force until the abutment was reached.

This bridge was over a ravine about two miles from the lake. At the lake this valley is about one-half mile in width, and at the bridge about the length of the bridge. Hence, it is funnel-shaped, not unlike á horizontal section of an inverted hollow cone, with its base toward the lake.

Gen. Meyer, Chief Signal Officer of the United States Army, says that between eight and nine o'clock P.M. the velocity of the wind between Erie, Pa., and Cleveland, Ohio, was from twenty-four to fifty-four miles miles per hour; and that it was probable that at the bridge there was a concentrated force of wind exerting an upward pressure against the closely laid floor of the bridge, and a direct pressure against the train, all acting as a lever tending to crush the south truss.

On that evening, the train came on to the bridge on the south track, over the south truss, laboring through the deep snow. It is immaterial whether the forward engine suddenly put on all of its steam, and the second one the air-brakes, or whether the wind was twenty-four or fifty-four miles per hour, or whether it was one or all of these forces combined, or from any other cause, if there was a sufficient amount of oscillation produced, the lateral wave would increase in violence toward the west butment, and the strains would naturally accumulate in the braces toward the west abutment in the south truss. Then, as each brace acts separately, and, to a certain extent, independent of all others, and at these points where the resultant force had so accumulated, the braces would bend laterally, one by one, in detail, and yet the whole set almost simultaneously, and allow the top brace-blocks to fall down against the lower brace-blocks on the vertical rods. And thus the train would be thrown to the south, and the bridge go down.

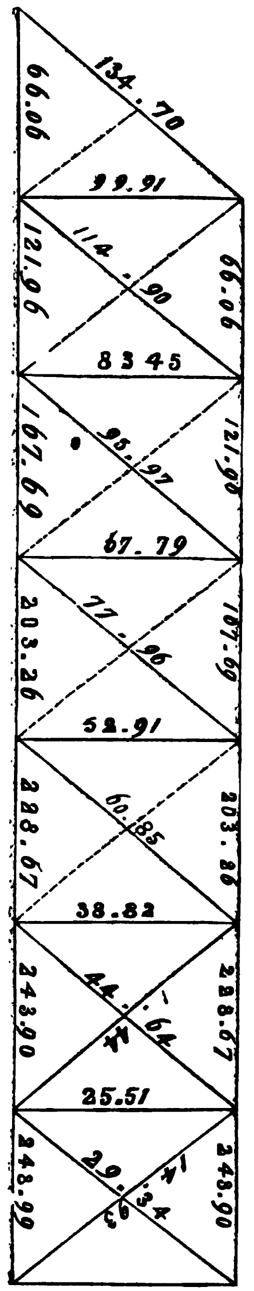
Now, had this been a single track bridge, the lower chords would have received equal strains in tension, and there would have been very little oscillation, and very little lateral bracing required between the lower chords. Or, on that double track deck bridge, had there been two trains, one on the north track and one on the south, both of the lower chords would have been in tension, and the rectangular position of the trusses to each other would have been maintained, very little vibration would have taken place, and, in all probability, the bridge would have been standing to-day.

If the braces of this bridge had been latticed, they would have given different results. As it was, they acted separately and independent of each other, and if the number had been increased at the points shown to be weak, it would not have made the bridge secure.

Although the top chord shows no lateral bending of the I beams between panel points, yet at the same time they should also have been latticed.

For the information of your committee, a strain-sheet of the wrecked bridge is hereto attached.

Maximum strains assuming live load to be 4,000 pounds per lineal foot and dead-weight being 393,122 pounds. Panel load, live and dead, 18.02 tons.



BRACES.

No. of panel.	Total strain, in tons.	Total area of brace.	Strain in compression per sq. inch.	Factor of safety.
1	134.70	66.6 in.	2.022	3.7 tons.
2	114.90	57.6	2.	3.7
3	95.97	36.9	2.6	2.9
4	77.96	26.55	2.93	2.5
5	60.85	26.55	2.29	3.3
6	44.64	26.55	1.70	4.4
7	29.34	26.55	1.10	6.8

TOP CHORD.

No. of panel.	Total strain, in tons.	Area of beam.	Strain in compression per sq. inch.	Factor of safety.
2	66.06	45.76 in.	1.44	9.1 tons.
3	121.96	45.76	2.66	5.
4	167.69	49.50	3.38	3.9
5	203.26	54.10	3.75	3.5
6	228.67	60.90	3.75	3.5
7	243.91	62.30	3.91	3.3

BOTTOM CHORD.

No. of panel.	Total strain, in tons.	Area of beam.	Strain in compression per sq. inch.	Factor of safety.
1	66.06	48⅛ in.	1.378	22. tons.
2	121.96	48⅛	2.53	11.8
3	167.69	48⅛	3.49	8.6
4	203.26	55.	3.70	8.1
5	228.67	68.75	3.32	9.
6	243.91	68.75	3.55	8.4
7	248.99	68.75	3.60	8.33

TRUSS RODS.

No. of panel.	Size.	Area.	Strain per inch in tons.	Inches in excess.	Factor of safety.
1	$2\frac{1}{8}$ round.	28.68	3.48	8	8.6 tons.
2	2.	25.39	3.24	8	9.2
3	$1\frac{7}{8}$	22.32	3.00	8	10.
4	$1\frac{3}{4}$	19.44	2.72	8	11.
5	$1\frac{5}{8}$	16.76	2.31	9	13.
6	$1\frac{5}{8}$	16.76	1.52	11	19.

There is a large excess of material in the lower chord.

FOR BREAKING LOAD.

30 tons were taken as the tensile strength of iron per inch.

DEFLECTING LOAD.

7.56 tons were taken for I beams 21.5 feet x .5 in compression iron per inch.
13.2 " " " 11 " x 5 " " "

Respectfully submitted,

W. S. WILLIAMS.

CANTON, OHIO, *February* 14, 1877.

TESTIMONY OF M. J. BECKER.

M. J. Becker testified as follows:

Q. By Mr. Converse: Please state your name, age, residence, and profession.

A. Name. M. J. Becker; age, 49 years; civil engineer by profession; residence, Pittsburg.

Q. What experience have you had in engineering?

A. I have been practicing the profession with, perhaps, the intermission of two or three years, for the last thirty years consecutively.

Q. Where have you practiced it, and how are you now engaged?

A. I commenced the practice of engineering in Europe, and after coming to this country, at the age of twenty-one, I became engaged, in a very short time after my arrival, on the old Steubenville and Indiana road, which is now a part of the present Pittsburg, Cincinnati and St. Louis road. I was then employed as a draftsman for a short time, and afterwards as assistant engineer in charge of construction and upon location of lines; and from that time to the present I have been almost uninterruptedly engaged on that line of railroad. For the last ten years I have been its chief engineer.

Q. What do you mean by that line?

A. I mean the line of railroad commonly known as the Pan-Handle.

Q. You may state whether you have made the subject of engineering a study, embracing not only the practical part of it, but the scientific principles upon which it rests?

A. I was educated for that purpose. I have devoted almost my entire time and attention to the acquirements of the theoretical knowledge, and in the employment of my profession I have had opportunities for practical experience.

Q. If you have a span of 154 feet for the construction of an iron bridge, panels of eleven feet, vertical depth of twenty feet, width about twenty feet, two trusses, and you find the braces in such a bridge as that composed of iron beams known as I beams twenty-one feet long, oblique, six inches by four, and suppose that the braces were composed of a number of such I beams, fastened only with a stirrup in the center around the counters and main braces, the stirrup to be composed of inch iron round bar, how would you calculate the strength of such a beam? I mean, how would you calculate it, as a beam twenty-one feet long or as a beam one-half that length?

A. Taking the situation as presented, I would, in calculating the necessary dimensions of such braces, treat the columns as twenty-one feet long, and compute the necessary sections from that assumption. I wouldn't consider the mere strap, winding around and fastening in the center at the point of intersection of the main braces with the counters, alone as a sufficient safeguard against flexure in the middle. There is nothing to prevent the entire system, strapped together as it is, from yielding, at least in a lateral direction, from right to left, or vice versa, whenever a strain becomes sufficient to cause that lateral yielding. The straps might possibly prevent a tendency of movement in the direction of the bridge, but it wouldn't prevent any lateral movement bodily. It might also prevent a separation of the parts composing the struts by the yielding of the members outwardly. What I mean is this: Supposing, for instance, that the pressure applied on the top of the column would act in a direct line, and perfectly parallel to the members composing the column, and that the pressure would be sufficient to spread the members by bulging in the middle of their length, one-half of them bending to the right and the other half to the left; in such a case, the strapping around the point of intersection might act as a preventive; but if the pressure on top was any way oblique, tending to force the entire column bodily out of line, such strapping would, in my opinion, not be sufficient to prevent it. At any rate, I do not think it safe to take the effectiveness of these straps into account in calculating the resisting power of the column, and I would treat these braces as being of twenty-one feet length, and unprovided in the middle with means to prevent lateral flexure.

Q. Shall we understand you to say then, that while such an arrangement around the centre braces might tend somewhat to strengthen them, yet a prudent engineer would not rely on such an arrangement to prevent deflection, and would not calculate upon it?

A. I do not wish to be understood as saying that these straps were wholly and entirely useless, for if I were asked the question whether they would resist a tendency to separate the members and prevent their bulging and spreading outwardly, I would be compelled to answer that they would resist such a tendency, provided the line of pressure was perfectly parallel and coincident with the members of the brace; but it would not, in my opinion, be safe nor prudent to presume upon the chances of such a contingency. If the pressure would act in an oblique direction with sufficient force to deflect the brace to one side or another, the entire system would be pushed out of place together, braces, straps, and all. A prudent engineer should provide in his calculations for the extremest cases that might arise, and not presume upon any doubtful chances in favor of security.

Q. What would you say as to the propriety of building a bridge for railroad travel, and over such a chasm as I have mentioned, to use oblique braces of wrought iron? Is that in accordance with the highest skill of engineers?

A. Well, I have never seen braces of wrought iron used in that form, at least not without such a connection of all the parts, between each other, as to act as one united strut or beam. Whenever wrought iron is used in the form of channel bars or I beams, they are always, in well-constructed bridges, bound together, generally with diagonally arranged lattice-work, forming a triangular system of bracing, so as to act unitedly and to bring the entire surface into play.

Q. That would make each brace a truss of itself?

A. Yes.

Q. What is your recognized formula for calculating the strength of a beam such as I have mentioned—an I beam six inches by four?

A. Well, there is a formula used in this connection that provides for the resistance to crushing, in connection with the tendency to lateral flexure. It is an old formula, that answers in most cases, called Gordon's, which takes into account both of these elements, but there are other formulæ, that have been developed from experiments made with the different forms of iron, and each form has a factor of its own, so that there is no one particular formula that applies to all cases. If a strut is made of hollow cast iron, circular in form, one formula might apply; another would apply to a square, and solid. There is no one particular form that would apply to all the cases, but in every particular instance this item of flexure must be taken into consideration, in such lengths of beams as these.

Q. What is the dimension and strength as compared with the length of beam?

A. That depends, to a considerable extent, upon the form of the beam.

Q. Suppose you take an I beam form, can you give us any authority, or formula, or definite statement as to the manner in which this calculation can be made as to the strength of the braces, considering its length and size?

A. I couldn't give you any positive formula that would apply to this case, without referring to some books and see just what formula to apply; but the effective strength diminishes as the length increases. If you take a piece of plank two inches by twelve inches, and twelve feet long, and apply a weight on top, you will find that that board will soon begin to bulge out sideways; you take that board and rip it into four pieces, each piece three inches wide, and nail those pieces together, one on top of the other, or in the form of a square box, and you put that weight on top again, you will find the pile or box won't bulge in any direction, although there is no more material in it than in the plank originally, and the sectional areas are exactly the same. This is merely an illustration, to show that the resisting power is largely modified by the shape of the column.

Q. I will ask you whether the fact of a beam resting upon a solid surface has anything to do with the strength of it? I mean if it should rest upon a smooth and solid surface, whether its strength is increased or diminished than what it would be if it rests on an uneven surface?

A. Its strength is greater when resting upon a smooth and even surface.

Q. Is there any rule on that subject?

A. The rule that is generally adopted is, that when the ends of the beams rest upon smooth and planed abutting surfaces their strength is about three times as great as when both ends of the beams are rounded off. That is the general formula.

Q. Suppose, in a bridge such as I have mentioned, you have beams of the shape I have mentioned, and suppose that the base blocks above and below that they rest upon or brace against, have a strip two inches or two and one-half planed down lengthwise through the centre, so that the flanges of the I beams rest above and below this planed surface, the planed surface being sunk or cut down the thirty-second or sixty-fourth part of an inch, how would you account a beam so resting as that?

A. It couldn't be classified as coming under either head. It certainly would not bear uniformly on all its parts, yet it could hardly be considered as a rounded end surface. I should say it would be something between the two, but just how much, it would be very difficult to say, unless I could see the actual condition of the blocks.

Q. When you speak of a smooth plane for an end beam to rest upon, would simply a casting that had been chipped off with a cold chisel, would you regard it as smooth?

A. No; I would consider a casting coming from the foundry and rubbed off, such as they usually do—taking one part of a casting and rubbing it against the other one—as perhaps filling the requirements of a smooth plane, although it might not be planed, but from what I know of attempts to chip off the roughness of castings, I should say that a nice, smooth plane would not likely be made by chipping. I have never seen a neat job made in that way.

Q. It is stated, in this Ashtabula bridge, that the braces of the upper chord were composed of beams twenty-two feet long, and that a portion of the beams rested against the lug on the top brace blocks, while the other beams passed over the top of the brace blocks, and were only held down to it by clamps, while the beams might have a lateral motion of two and one-half inches. How would you calculate the strength of such a member as that, with such a play as that between the lugs on top of the brace blocks?

A. Well, I think I would be willing to allow the full cross sections of the abutting surfaces, as far as the crushing of them is concerned. As to their resistance against flexure, what I have said in regard to the braces would also be applicable in this case.

Q. It is said that these members of the upper chord were I beams, six by four, and that they were fastened together every five feet by three-quarter iron round rods, with a thimble to keep them sufficiently apart, and then alternately two and three bars passed over the brace blocks having this play, which I have mentioned, what provision ought to be made for fastening members in an upper chord, in such a case as that?

A. Well, it would be better to divide the chords in lengths of one panel, and provide for the abutting surface there so as to shorten the length of the column and at the same time provide an effective system of lateral bracing, which ought not to run more than one panel length; in this way a tendency of flexure would be almost entirely counteracted, and where you permit them to run, say two panel lengths, without any stiffening, I mean external stiffening, it would require something in the shape of lateral bracing to give them lateral stiffness, to guard against bulging outward or inwardly, and that could be most effectually done by close lateral bracing. Of course when you calculate the strength against flexure of the top chord, if it runs over two panel lengths without being secured, you must consider it as a strut of two panel lengths, and treat it so in your calculation. I say also that the tying together of those five members of the top chord, between each other, would not counteract any flexure of the whole body, either to the right or left; of course, tendency to bulge upward or downward is not likely to occur, and the only tendency would be horizontally right and left, and against that the counter braces would have to be introduced as a preventive.

Q. I will ask you then, how near ought these counter braces to be introduced to prevent that sort of lateral flexure in the upper chord, and what name do you call this counter brace?

A. We generally call them lateral braces, or call the horizontal ones generally lateral braces, and those that run diagonally downward, connecting the bottom chord on one side with the top chord on the opposite side, we generally call sway braces.

Q. How near ought those sway braces to be, in such a bridge as I have described?

A. I think I wouldn't place them farther apart than a panel length, though I will admit it has been the practice, especially in wooden Howe truss bridges to run them some times to an angle of forty-five degrees, regardless as to what particular part of the truss they would strike. At an angle of forty-five degrees, the clear space between the chords of a deck bridge would be about equal to the usual length of a single panel. In single track iron bridges the lateral brace system is generally introduced in every panel.

Q. I will ask you what the rule is for determining the size of these sway braces, if there is any?

A. That is a matter depending somewhat on the action of the wind; in wooden covered bridges that is a chief element that you want to guard against, but it doesn't amount to a very great deal in an open iron bridge. There is also a tendency, where the bridge stands on a curve, to push out in the direction of the tangent, and that has to be guarded against by lateral braces, so that on a curve the lateral braces should be more effective and stronger than on a straight line; and in any event I wouldn't like to adopt, for a bridge of that kind, rods in the middle of a bridge of less than one and one-fourth inch in diameter; and I would have them at every panel, and in no event would I place my braces at an angle more than forty-five degrees.

Q. I want to ask you this question: How do you calculate the strength of a piece of iron, in compression, suppose it is where it is subjected to vibration; do you calculate it the same as if it was resting upon a solid surface above and below?

A. No; I don't think there are any calculations made to ascertain the effect of vibration, except that where a bridge is greatly subjected to such vibration I would take the precaution to allow a greater factor of safety, than for ordinary contingencies, but I don't think it is possible to ascertain with accuracy the exact effect of such vibration over and above the strain that arises from the loads and weight of the structure.

Q. If you were to take a beam twenty-one feet long, suppose it was subjected to vibration, would it be strained to a greater extent when subjected to vibration than if it rested upon a permanent base, and had permanent dead pressure above?

A. There is no doubt the dead immovable load upon it would be easier on the strut than a movable vibratory load of equal amount.

Q. On a long brace like that, I will ask you, whether the vibration, as of a moving train rolling over a bridge, doesn't tend to throw the line of pressure outside of the axis of the strut and thereby weaken its strength?

A. It would certainly subject it to a far greater shock, there is no question about that; but there is no fixed rule by which you could provide for its vibration, unless you take a larger factor of safety, and introduce measures to increase its stiffness by bracing or tieing.

Q. Would it be the duty of a prudent engineer to take that larger factor of safety?

A. Yes, sir; I should say so. I think it is but proper that every engineer should do so.

Q. In putting my supposed case awhile ago, of the braces resting upon brace blocks, that had been chipped by the cold chisel, and a strip planed off from two to two and one-half inches wide, on which the beams didn't rest at all, I included the motion, and put the supposed case; I will ask you to state how it would effect the strength of the beams, supposing the corners were chipped off, in addition to these other facts.

A. If it was irregularly chipped off I think I would disregard the chipped-off part entirely in the calculation, and make a deduction in the cross sectional area, corresponding to the chipped-off piece.

Q. What effect would that have in calculating a beam, as to a round end, or flat end beam, with the outer edges of the flanges chipped off?

A. It all depends upon the amount of the injured base, and the roughness in which it is left. That is a thing that would have to be taken into account, to the best judgment of the engineer, having the calculation in hand; it is very difficult to say just to what extent it would effect it, it certainly would have a tendency to weaken the effective strength of the strut.

Q. Suppose in the examination of a bridge of this kind, you were to find that these braces had slipped down and up, on the brace-block, in some case as much as three inches, and in others two inches, and others one and one-half inches and some perhaps not more than half an inch, what would you say was the cause of that slipping? Ought it to be guarded against? How ought the beam to be calculated that had slipped out of its place in that way?

A. The slipping may be caused by insufficient bearing, probably on account of looseness in the tension rods, which may not be sufficiently tightened up, to maintain the braces in place, and it might be owing to the fact that they were of unequal length, two or three of them filling the exact space, and one being a little shorter, would necessarily have to remain loose, and that thing ought to be immediately looked after and guarded against. In the absence of a more effective remedy it would, in some cases, be sufficient to interpose a sheet of lead or metal of some kind which would be impressed by the force, and afford an even bearing to all the members. This looseness of the braces is a very serious defect and ought to be remedied as soon as discovered.

Q. Supposing you were called upon to calculate the strength of a beam of that kind, how would you arrive at it? How would you, as an engineer, calculate the strength of the beam?

A. Having slipped out of place?

Q. Partly slipped out.

A. It might not bear a pound; there might be, as I said, three out of five bearing the whole load, and the others a quarter of an inch short not bear any thing.

Q. In calculating, then, the strength of beams, such as I have supposed, length, shape, and location, would you calculate them as round end beams or not in calculating?

A. I think I would, perhaps, be willing to give a little larger allowance than round end beams. Round end beams rest, really, on a theoretical point, and I think it would be getting the thing down to a low base of calculation on that presumption, and there ought to be some thing between a round point and a square end; but what proportion, can only be determined by the roughness of the surface and the damage of the ends of the struts. I wouldn't like to say without seeing the particular pieces.

Q. What is the margin of safety in all calculations on iron bridges?

A. Well, opinions differ considerably on that subject; some of them, feeling confident in their own work, are satisfied by allowing a factor of safety of four. More careful men make it five, and I think six would be nearer to perfect safety.

Q. Do you make any difference between members in compression and in tension?

A. Not generally; I would make perhaps a difference in the more important members of the structures, and increase their factor, while I might diminish that of members of not such vital importance.

Q. Would you make the factor of safety alike as to members of compression and in tension?

A. I would for members of equal importance.

Q. In other words, your metal wouldn't support so much in compression as in tension?

A. The capacity of resisting is greater in wrought iron when under a strain of extension than when under compression; but that does not affect the allowance for safety.

Q. You said, a moment ago, that these sway braces ought to be at every panel in an important structure such as I have described, and that the rods ought to be an inch and a quarter in diameter. Suppose they are set at every other panel, then what ought to be the size of the rods?

A. Well, the size wouldn't help the matter a great deal; the tendency to flexure ought to be counteracted by more frequent introduction, rather than compensated by a larger amount of material. I think a lighter rod, more frequently introduced, would be much more effective than a large rod running over a longer range. There ought to be some little increase, in proportion to the run they are placed in. You asked me whether the crosssectional are a of metal should be made heavier in compression than in tension, I believe I said it was alike. I didn't mean to say that; wrought iron will resist a tensile strain much easier than a crushing strain, even on short columns.

Q. Suppose this sway bracing is fixed at the point where there is no strut or counterbraces, what have you to say then as to effectiveness?

A. It simply has no effect at all; the strut, placed away from the tension of the lateral rods, would be of no account; neither would the rods be of any account without an interposing strut; the two can only act together.

Q. And they are only effective when the rod is fastened at the head of the strut?

A. Yes, sir.

Q. I will ask you whether that would be so no matter where it occurred.

A. Any where; the tension rods could not be effective without an interposing strut; he two systems must go together.

Q. What is the value of iron, in its power to resist in compression, and what is it in tension, to the square inch?

A. In tension, good iron ought to sustain a pull from fifty to sixty thousand pounds to the square inch.

Q. How much in compression?

A. They pretend to say that in short pieces it will stand from seventy-five to eighty thousand, but I have never seen such a test verified.

Q. How ought that now to be diminished? In what ratio does that sustain to the length of the beam?

A. Whenever a beam or a strut reaches a length which exceeds say from eight to ten times the diameter or the square of that strut, then it is weakened by means of lateral bulging; flexure begins, and increases with the increase of the length.

Q. Can you give me some idea as to the value of brace beams 21 feet long, I in shape, and 6x4 inches?

A. Well, I wouldn't like to guess at a thing of that kind; it is a matter of calculation. The form of the beams, the size of its web, the size of its flanges, and all that, would have to be taken into account; and, without some closer calculation, I wouldn't like to venture upon a hap-hazard expression.

Q. Well, you say the power to resist compression in iron may be seventy-five or eighty thousand pounds to the inch; what is its power to resist—I had better say buckling, or flexure?

A. That depends entirely upon the length, form, and the cross section.

Q. Length and shape?

A. Yes; by giving a fixed form, and fixed length, we can tell you by very little calculation just about what the thing is able to do.

Q. What remedy is there, if any, in your judgment that might be applied by the law-making power of the State to diminish the number of accidents like this Ashtabula bridge disaster?

A. Well, I don't like to venture upon an opinion in regard to that; but since you ask the question, I would like to refer you to a report which was made some three or four years ago, after the breaking down of the bridge at Dixon, Illinois, by a committee composed, I think, of eight members of the American Society of Civil Engineers, which is a society numbering now, I think, some six hundred members. The members of the profession are only admitted on ballot, after recommendation by a committee of the society. Those gentlemen investigated that question fully at the time—spent nearly a year at it; and then the eight members, being somewhat at variance in their views, submitted, I think, five separate reports. They classified the causes of accidents into three groups. The first one embraced accidents arising from faulty construction, either badly drawn plans, or imperfect workmanship, or insufficient material; in other words, causes arising from faulty construction generally. The second class embraced failures through neglect of structures that were originally put up in good shape, and were permitted to go to ruin from the want of proper attention by their owners. Then there was a third class of accidents against which the committee proposed a remedy—such as were caused by violence, tornadoes, destruction by fire, collisions, or derailment of railroad trains. Then the gentlemen went on to touch on legislation to prevent repetition of such a disaster as they had investigated. They were nearly unanimous on the general remedies, although they differed considerably on the details. They proposed, in the first place, that there should be in each State an expert appointed by the Governor, who should have general supervision over the construction of bridges, and the plans of all structures to be erected, either by railroad companies, or county, township, or city authorities, should be submitted for his approval, and not be erected without his consent; and if the structure be of such importance as to warrant it, he should superintend it, or send some one there competent to do so; and, in case of an accident, he should report and hold the parties responsible. And they further proposed, at the same time, a sort of standard by which these experts should be guided in their determinations. They would, for instance, say, for highway structures in a city of large traffic and large manufacturing, the floor should not be loaded with more than one hundred pounds to the square foot, and the calculation based upon that presumption; in more remote parts of the country they would reduce it correspondingly. And then they prescribed the amount of material to be put in to resist certain strains, prescribing them in detail; in other words, they advised a certain standard that should be considered the governing schedule from which to work. Now, as far as my own views are concerned in regard to this matter, I think that a proper supervisory officer in each State could do considerable good. He could not, of course, do away with all the bad bridges we have on hand, but certainly he could prevent any new ones from being put up hereafter. And, as far as the State of Ohio is concerned, if the present Board of Canal Commissioners, with their attendant engineers and supervisors, and the present office of Railroad Commissioner, with his attendant bridge inspector, could be merged into one competent board of three experts, that would either divide the State geographically, or would take general supervision over the whole of the State, in the manner as the Society of Engineers suggested, I think there would be some good arising from that. Now, such a bridge as that at Ashtabula should never have been built, and I am confident if that plan had been submitted to a competent board of engineers, before its erection, that bridge never would have been built.

Q. What information did you have as to the size of the braces in that bridge?

A. I have seen the plan in Mr. Johnson's office, and have looked at it carefully.

Q. By Wiltsee: How many miles of railroad have you now in charge?

A. About twelve hundred.

Q. How many bridges, and what is their combined length?

A. There are about five hundred and fifty in all; what their combined length is I can't exactly say.

Q. Their average?

A. Well, I couldn't say; they average, I suppose, about one hundred feet in length. We have a good many of greater span, and, perhaps, a larger number less.

Q. On your road, are there any built like the Ashtabula bridge?

A. Nothing like it; no, sir.

Q. Do you know of any, or did you ever know of any, except that, built in that way?

A. I only know of one iron bridge that has been built in imitation of the principles of the old wooden Howe truss, and that it is located at Bridgeport, opposite Wheeling, on the Cleveland and Pittsburg Railroad. My recollection of that bridge is that its compressive members are composed of cast iron, but the combination, and the manner of putting the parts together, I think, is very good; at least, it impressed me so at the time I last saw it, but it is entirely different from the Ashtabula bridge in its execution, or combination, of its parts. With that exception, I don't know of any other iron bridge in which that system has been carried out. The reason for it, I think, is because it is not an economical form of structure. In your question about the compressive strength of iron, you didn't specify whether you meant wrought or cast iron. Mr. Johnson thinks you had reference to wrought iron.

Mr. Converse—I did.

A. Inasmuch as cast iron has greater compressive strength than wrought iron, I took it for granted you wanted the metal that had the greatest resisting power, and therefore I mentioned the figures when I said 75,000 or 80,000 pounds. Compressive strength of wrought iron is not as great as that of extension.

Q. I will ask you to state whether cast iron, except for blocks, rests, or something of that sort, is suitable material to put in bridges, in your judgment?

A. In the earlier period of iron bridge construction, cast iron has been almost exclusively used for all compressive members, but more recently it has been generally abandoned, and wrought iron has been substituted in its place. I always feel more safe on a wrought iron bridge that hasn't any important cast iron parts in it, although we have on our road, and on almost every road in the country, very excellent iron bridges built at an early day which have cast iron braces in them, and show no signs of trouble of any kind.

Q. I will ask you if you saw the plan of this Ashtabula bridge, and the mode of connecting the braces with the chords, and, if you will be kind enough, to state whether you considered it a safe and proper way of connecting?

A. If I understand the plan correctly, or recollect it right, there is no connection between the braces and the chords—they merely rest against the angle-blocks, above and below. There should be certainly some provision made to secure them in place.

Q. How ought that connection to be made?

A. Well, its manner of construction is so singular in its whole arrangement that I don't know how it could have been effected with this plan, but the usual mode of connecting the oblique members is either by screw bolts or by rivets or by pin connections and eye bolts. I always considered the link and pin connection as the safest and best.

Q. I will ask you whether it would be possible for braces in such a bridge as the Ashtabula bridge to deflect from the line of their axis and still do duty for any considerable length of time.

A. No, sir. They are only effective when they stand in their proper direction, and whenever they deflect they cease to be effective.

Q. Where they are out of line would it be considered a great negligence not to straighten them up or to cease to use the bridge?

A. I would certainly consider it my duty, whenever I found a brace out of place, to replace it and secure it thoroughly, to prevent it slipping out again.

A. In calculating the strength of these five or six I beams entering into a single brace, as at this Ashtabula bridge, should they be calculated as separate braces, or should they be calculated as one solid brace for the calculation of the area of the several braces?

A. Without any more perfect connection of the parts between themselves, I should be disposed to calculate these struts and top chord pieces singly—each piece for its own effective resisting force, and I should simply multiply that by the number of pieces. If they were rigidly connected between each other, then they might with propriety be considered as one column.

Q. Would that be the only safe way to calculate?

A. Yes.

REPORT OF A. GOTTLIEB.

* * * * In reviewing the details of the construction, I would like to state beforehand that the Howe-truss pattern is not very well adaptable for heavy iron bridges, as they are necessary for all railroad traffic, for the simple reason that it contains too many compressive members, which, if properly constructed, requires much material, increasing thereby the dead-weight of the bridge considerably. The bridge is less fit to sustain a live-load, if she has in the first place to hold up a heavy dead-weight. When the wrecked bridge was constructed, the building of iron truss-bridges was in its childhood, compared with the progress made since that time. A stronger and uniformly well constructed bridge, even of the Howe-truss pattern, of the span of the Ashtabula bridge, with double track, should, nowadays, not have a larger dead-weight than 1,800 pounds to 2,200 pounds per foot, including track and all.

The first objectional point in the old bridge, therefore, was the unnecessarily great dead-weight.

The second is shown by the figures to be in the top chord.

The weakness of the top chord was still more increased by the following circumstances: The connection, laterally, of the single beams forming the top chord, was effected by bolting them together every five feet with a bolt five-eighths inch in diameter. This connection could not have been expected to transmit any strains from one line of beams to another parallel to it, and so each string was depending on its own strength to resist the strains received from the brace-blocks. The floor beams were resting directly upon the upper chords, without a bed-plate to distribute the weight uniformly over all the chord-beams; consequently some beams had probably to carry the main share of the total weight on the floor beams. The next weak point was in the bearings of the main and counter-braces on the cast-iron blocks. The bottom blocks were, during the examination, so covered with snow and ice and under water, and, being still connected with the iron work, unaccessible. But so many of them as could be examined, and the top blocks out of the water, showed clear marks on the face of the blocks where the braces rested on, the surface of the blocks covered by the shape of the beams remaining free of paint, while the surrounding surface was painted.

By these marks it is to be seen that some of the braces had a bearing with only flange and about one-half of the web, while the other flange and half-web was unsupported. Others had about four or five inches of their depths on the block, the balance of their height, unsupported; very few had a full bearing on the blocks. In some places considerable chipping had to be done during the erection of the bridge, in order to get the braces on the blocks at all, because the flanges and webs of the beams interfered with the truss-rods, which came nearly in the same place through the blocks where the beams were intended to rest. These imperfect bearings of the braces on the blocks, may have brought the strains edgewise through the beams, in place of parallel to the center axis, vertical to the ends, and may have weakened the resistance of said braces to such an extent as to make the excesses of sectional areas shown for the braces to disappear partly or entirely.

The next objectional point was the arrangement of having lateral brace-panels of double the length of truss-panels, leaving, every time, one panel point without lateral support. This was undoubtedly done by assuming the top chord sufficiently rigid, laterally, for the length of twenty-two feet, which it probably was; but considering that the lateral rods were not adjustable in their length, and that by slackening of any of them from any cause, a considerable portion of the trusses would have to rely on the stiffness of the chord, the inserting of lateral struts and rods in each truss-panel would seem to have been advisable.

The same as here stated of the lateral rods, is in still greater a measure to be applied to the vertical diagonal rods, or vibration rods. These were adjustable, having a turn-buckle at their center. But the fastening of the ends of these rods to the cast iron brace-blocks, was, according to my mind, the weakest point in the whole bridge. The leg-screws connecting the ends of vibration rods with the blocks, were of three-fourths inch iron only, and between threads of the screw about five-eighths of an inch.

The only top block that had the vibration rod still connected with it in the wreck, that I could see, was near the east end of the bridge. A man trying to get the screws out with a monkey-wrench, broke the leg-screw off in a few minutes, leaving the balance in the block. I have the broken piece in my possession. Judging from the position of the bridge wreck, and that of the train at the bottom of the river, one lying entirely on one side, the other on the opposite side of the longitudinal axis of the bridge, the chances are in favor of the assumption that the vibration braces failed from some cause, and, letting the train slide down from the bridge on the side where the loaded track was, brought the bridge to the other, the movement probably starting near the center of the span.

The prime cause may have been an engine or car off the track, or any other sudden jar.

Another possible cause of rupture was the circumstance that the top lateral rods were held in the hutch of the top blocks by the weights of the upper chord-beams resting on them. By examination of the plan, it will be found that the heads of the two top lateral rods, meeting at the top block in center of the trusses, were held in their position by two I beams, that were spliced at that point, bearing against the lug of the block. If the top chord deflected under the engine load, it pressed the part of the lateral rod directly under it, downward, and, as the spliced outside I beams of the chord deflected also, the space then, and the lug on the block, may have been so increased as to permit the heads of lateral rods to slip out of their hold, that was only one-half of an inch, destroying in this way the top lateral bracing.

REPORT OF JOHN D. CREHORE.

I have made a partial examination of the ruins of the Lake Shore railroad bridge at Ashtabula, a complete examination having been impracticable up to the present time, for the reason that a large portion of the structure lies under the ice. I shall therefore not attempt a thorough and complete presentation of the condition of every part of this bridge, but shall confine myself to certain conditions of the structure, which should not be repeated in any future bridge building, even if it shall be proved that an excess of material in the ill-conditioned parts of this bridge neutralized their destructive tendency; for excess of materials is excess of dead weight.

The supporting frames, or girders, of the fallen bridge, were two wrought-iron Howe trusses, with a space of fourteen feet and five inches between them. These trusses supported two tracks seven feet apart.

The principal members of the Howe truss are, the chord to resist compression, the bottom chord resisting tension, the verticals also in tension, and the diagonal braces under compression. The space in the plane of the truss between the centers of any two consecutive vertical members is called a panel, or a panel-length of the truss.

Of the two braces intersecting at the center of any panel, that one is called the main brace which slopes or points downwards toward the *nearer abutment;* the other is called the counter brace. The main braces only are called into action when the bridge weight and the added load are uniformly distributed along the entire truss. The office of the counter braces is to preserve the rectangular form of the panel under a partial load, or, in other words, to transmit a fraction of the partial load toward the remoter abutment without distortion of the panel. At the panel points, both top and bottom, are cast-iron brace-blocks, through which the vertical tie rods pass, and against the sloping faces of which the braces abut. These sloping faces of two opposite brace-blocks should be at right angles to the abutting brace; and for the greatest efficiency of a brace, its extremities should have a bearing upon the blocks and be secured in position. The blocks must also be fixed.

In the Ashtabula trusses each diagonal brace consisted, so far as I observed, of heavy six-inch I beams, varying in number from two to six, according to the place of the brace. The brace-beams, main and counter, were tied or strapped together at their intersection in the center of each panel, to prevent deflection in the plane of the truss. This tying of their centers would not prevent their possible simultaneous deflection in the same direction, out of the plane of the truss.

The I beams composing these braces had their webs parallel to the plane of the truss, as the impressions upon the brace-blocks indicate.

There were projections, or lugs, cast upon the upper edge of the brace-bearing face of the upper brace-block, to prevent a slipping of the ends of the brace-beams from the block towards the top chord, and some of the upper blocks have the lower edge of the brace-bearing face raised a little as if to prevent the slipping of the brace downward between the vertical rods. But these projections or lugs were manifestly cast for a different brace, or for a different position of the brace used, for the lugs were fitted to brace-beams six inches wide in the direction at right angles to the plane of the truss, while the I beams actually employed have a width of only four and a half inches in that direction.

If these brace-beams should be turned so as to bring their flanges parallel to the plane of the truss, they would conform to the position of the lugs on the blocks, thus indicating that the braces were finally placed in a position different from that originally designed for them. This turning of the brace-beam through a quarter of the circle would not increase nor diminish the strength of the beam as a strut, but would give room for more beams to abut upon the same block.

But the want of conformity to the projections designed to hold them in place, rendered many of the braces dependent for their permanence in position solely upon the continuance of a sufficient end pressure on each individual beam, and whether this constancy of end pressure could be depended upon in a bridge doing the duty expected of this one, is now the subject of inquiry.

The designer of the bridge evidently supposed the lugs necessary, or he would not have placed them on the blocks. The virtual abandonment of their protection, by changing the position of the brace, or rather by omitting to supply some substitute, was at least an imprudent venture. Some of the upper brace-blocks show that brace-beams were out of their proper places previous to the fall of the bridge. Whether they were improperly placed at first I know not.

For instance, in the north truss, which was not directly under the fatal train, the upper block at what seems to be the fifth joint from the end of the bridge, shows the impression of one brace-beam that was bearing upon but three and one-eighth inches the full depth of the beam.

Other upper blocks of both trusses have impressions showing half flanges and whole flanges off the blocks, some upward and some downward, though I observed no other so great displacement as the one mentioned. The lower blocks I have not examined, nor indeed the upper ones fully, as they are partly under ice.

Among trusses with rectangular panels the characteristic feature of the Howe truss is, its having diagonal braces and vertical tie rods, instead of vertical struts or posts and diagonal ties. Now the diagonals are longer than the verticals, that is, the braces must be longer than the ties. But wrought iron resists tension better than its resists compression. Also its tensile strength is practically independent of the length of the bar; while a limit of length is soon reached beyond which a strut of given thickness will yield to compression by bending. Again, a given vertical pressure develops the least compression in a strut when the strut is also vertical.

For these reasons the Howe truss is not economical if executed in wrought iron, though it need not *therefore* be unsafe. The long wrought-iron braces require especial care in their construction and adjustment.

The braces we are considering were twenty-one and one-half feet long between their bearings. Calling the width of flange of each brace-beam four and one-half inches, which is a greater width than some of them had, we have the ratio of length to least side of rectangle about fifty-seven.

Using this ratio in the well-known approximate formula applicable to long struts, with the constants as given by Rankine, there results for beams bearing fully upon their ends cross sections, a breaking weight of 17,178 pounds to the square inch. But for struts with "rounded or hinged" ends, that is, with imperfect bearings, the breakage weight is 6,688 pounds to the square inch, or a little more than one-third of the former number.

Now, although the brace-beams have too much of their material in their webs, yet their total cross section is so great that an approximate estimate of the strain upon them indicates their sufficiency notwithstanding their faulty bearings; but the margin of safety is very small.

It remains to inquire whether the ends of the braces were really moving along their blocks up to the 29th of December. Upon first observing them I was inclined to think that they were gradually working off their blocks, very slowly indeed, as their eleven years of service proves. But upon learning that the bridge was last painted two years ago, I rëexamined the brace impressions, and found none that positively indicated any movement of the brace since the last painting. And if they had not moved in the last two years, they were probably stable in the position they had assumed. I would not, of course, state positively that no braces were further displaced at the instant the fatal train struck the bridge but such an unusual displacement seems improbable.

I will call attention to one other defect in the construction of this bridge, which should not be copied in a structure of this kind. It is the placing of the floor beams upon the top chords *between the panel points.* The top chords resist compression alone, and the deflection in them from this incumbent weight detracts largely from their efficiency, and may bring destruction to the bridge.

A careful examination and measurement of all the parts of this bridge will form the basis of the only complete calculation that can be made of the improper distribution of material in these trusses, and show how much the proper margin of safety was trespassed upon in their construction.

JANUARY 11, 1877.

TESTIMONY OF GUSTAVUS D. FOLSOM.

Q. What is your name, age, residence, and occupation?

A. My name is G. D. Folsom; I reside at 346 Lake street, Cleveland, Ohio, and am an engineer on the Lake Shore Railroad; my age is forty years.

Q. State whether you were on the engine at the wrecking of the Ashtabula bridge, and what was the first you noticed wrong at the bridge?

A. I was on the Columbia, the second engine drawing the train. As near as I could judge I was about two-thirds of the way across the bridge. The bridge began gradually to sink and to swing to the south, and then it recoiled and went to the north. It seemed that when the chord on the south side gave way the north chord recoiled and drew the bridge to the north. It was very sudden—the recoil was at the moment. The first sensation I experienced was the track giving away. I was applying the air brake very lightly. My engine struck the west abutment and seemed to be held a moment by the forward engine until the tender of my engine swung down against the side of the abutment. The iron express car shot under my tender while my engine seemed to be held. My engine fell on top of it. When my engine dropped down, striking the bottom, she turned over to the east endwise. The first I observed was both a settling down and a swinging to the south. It was storming very bad. I could not tell precisely when I was on the bridge. I shut off steam about four or six rods east of the bridge. We were running at the rate of from twelve to fifteen miles per hour. My fireman oiled the valves after I shut off steam, and had finished oiling before I noticed the sinking of the bridge. It would take not to exceed thirty seconds to do the oiling of the valves. My engine, at the moment of the break, seemed to plunge forward as if to go down in that direction, and struck the west abutment. I felt the jar when she struck, and then the back end of the engine and the tender swung down. I seized the throttle ratchel with my right hand and the air brake cock and pipe with my left, and was hanging by my arms with my feet downward till my engine dropped perpendicular and struck the bottom. I did not hear any noise as of breaking before I felt the settling and observed the swinging to the south, but while my engine was swinging down against the abutment, or while she was hanging for the moment there I heard two distinct and heavy crashes, and I thought then, at the moment when I heard it, that the train and bridge behind me were going down ahead of me—that is, before I dropped down the face of the abutment. My engine may have made one revolution from the time I noticed the sinking and swinging to the south before I felt her strike the abutment. The wind was blowing terribly strong. I think it was the worst storm I ever experinced on the Lake Shore. I could not give any opinion of the strength of the wind. It came rather from the northeast. I think such a wind would produce a good deal of effect on a moving train. The train was of ordinary heft for that road. My engine was the Columbia. The Socrates was ahead of me. The Socrates was a thirty-two ton engine, and the Columbia a thirty-five ton engine, exclusive of the tender. I had burnt, before reaching the bride, three-fourths of my tank of coal. I carried nine buckets to ten of coal, each weighing 1,250 pounds—that is, when full loaded. I operated over the road about nine years. I don't know that I ever heard the safety of the bridge questioned. I never really liked the bridge. I can't say I considered it unsafe, or I never would have run over it; but I did not like the bridge. I noticed in passing over it at times a snapping as if the joints were settling together. I heard that snapping, so to speak, but did not feel it. It was not a rattle or continuation of sound, but it was a snap, and when heard it was over with. I never, before that night, noticed any lateral motion to the bridge in passing over it. The pop on the engine was self-acting, and would relieve the boiler of any undue pressure. Soon as my engine turned over I dragged myself out. I was sensible all the time. When I undertook to step I discovered my right leg to be broken. I dragged myself out to near the south corner of the old abutment. Every thing was quiet except the moaning of the wind, and it was dark. When I got half way from my engine to the abutment I called my fireman. At the second call he answered, and said "for God's sake take this off me so I can get up." I told him I could not aid him, but would halloo. I hallood four times, and received no answer. Every thing was still and quiet. I then pulled myself up to the abutment. The next thing I noticed was the fire breaking out near the east abutment on the north side. Up to that time I had neither seen or head any one except the fireman. In one or two minutes three fellows came down by the abutment on the side where the stairs were. I sent them to relieve the fireman. They got him out. There were screams and cries for help shortly after I saw the fire. I remained about fifteen or twenty minutes near the abutment, and was then taken to the pump house. Before I was taken away the whole wreck was on fire and the noises had all ceased.

Q. What have you to say about your engine being off the track?

A. Nothing more than to give it an emphatic denial.

Q. Did you ever notice that snapping sound on any other of the bridges on the Lake Shore road?

A. No; I never did.

TESTIMONY OF AMASA STONE.

Amasa Stone, being duly sworn, testified as follows:

Q. By Mr. Converse: What is your full name?

A. Amasa Stone.

Q. What relation do you sustain or have sustained to the Lake Shore Railroad Company, and for what length of time?

A. In the building of it, first as superintendent, for about two years. Became its president, I think, about 1856 or 7, and remained until 1867—that is of the Cleveland and Erie Division. Since that time have been director.

Q. What year did you become president of the company?

A. I can't state definitely. I think it was 1855 or 1856, perhaps.

Q. When was this so-called Ashtabula bridge erected?

A. I think it was erected [examines paper] in the autumn of 1863.

Q. Who was the designer of the bridge?

A. I designed the bridge.

Q. State whether you superintended personally in detail the work; and if not, to whom it was intrusted?

A. I only superintended in making its plans. The detail of the iron work was done by Albert Congdon. It was supervised generally by Mr. Tomlinson.

Q. Have you the original plan of the structure?

A. I have not.

Q. Where is it?

A. I don't know, but suppose at the office of the chief engineer, Charles Collins.

Q. Were there full written specifications prepared at the time, and if so, where are they?

A. There were all the specifications that are usually given for the construction of a bridge. I have a copy here of the bill of materials that was given for the bridge.

Q. Were there or not any full written specifications made at the time?

A. There were full specifications.

Q. By whom were they prepared?

A. By myself, except in some minor details.

Q. Where is that paper or specification?

A. Well, that paper, I have in my hand, is all that I would want.

Q. That is not my question. Where are the specifications that were originally prepared by yourself?

A. I can't tell you, sir. That is a copy (referring to paper in his hand) of all the material part of the specification.

Q. When did you see it last, the written specification, made in connection with the plan of the bridge?

A. I have seen nothing of it since the bridge was built, until within a fortnight that paper (referring to same paper) was handed to me.

Q. By whom was this paper prepared and handed to you?

A. It was taken from the order book of the Cleveland Rolling Mill Company, and handed to me by my brother.

Q. Do you desire to make this a part of your answer (referring to same paper)?

A. Just as you please.

Q. Did you make out a strain sheet, in connection with the plan and specifications?

A. I made up the figures at the time.

Q. Where is that paper?

A. I am not aware, sir. Not preserved, as I am aware of.

Q. Was it preserved until the bridge was completed?

A. I am not aware that it was—no longer than that (pointing to paper), until that was made out—the bill of materials was made out.

Q. What was the span of the bridge?

A. One hundred and fifty-four feet between bearings.

Q. What was the width of the bridge, including the chords from outside to outside?

A. Nineteen feet six inches—that is my recollection. It may have been twenty feet.

Q. What is the width of the bridge between the chords, lateral?

A. Either fourteen feet, six, or fourteen feet.

Q. What was the width of each truss?

A. It was two feet nine inches in thickness, and twenty feet in height.

Q. Do you mean from outside to outside?

A. Yes.

Q. From the lower edge of the truss to the upper edge?

A. Yes.

Q. What was the width or length of the panel, and how many were there?

A. Fourteen panels, of eleven feet each.

Q. Will you state to the committee whether there was any change of plans after the work was projected by you?

A. There was none.

Q. In the construction, was there any departure from the original design, in the size, or strength, or any of the parts?

A. There was no departure. As the bridge was finally erected, an error was made by the parties who were raising it, and it gave them a good deal of trouble; and when remedied, the bridge was put up as designed.

Q. What was that error?

A. They put in the braces flat-wise, horizontal instead of vertical.

Q. State whether there were lugs cast to receive the end of the braces?

A. My impressions are that there were.

Q. How were those lugs cast to receive the braces, flat-wise or vertical, as you state?

A. Vertically, I designed it. I wasn't aware that there was an error in that in the detail.

Q. Were they not, in fact, cast so as to receive the braces as first put up?

A. I think not, sir.

Q. And were not the lugs chipped off with the cold chisel when the change was made?

A. They might have been. That is a matter I have forgotten about. It was an error in the detail of the work which I wasn't aware of, until I went down to the work, and found that the braces were wrong. If you will analyze that bill (pointing to paper), you will see that it is impossible to put the brace in flat-wise. It could n't be got in as they are put in there. They just fill the entire structure from end to end, and putting it in flat-wise would not have filled it. They were designed to be put in as these (referring to paper).

Q. Was not the original design of those braces to be six inches in width?

A. No, sir.

Q. What was the original design?

A. It was four by seven; that is my recollection. There was but one bill given, and that is correct.

Q. Can you state whether the lugs upon the brace blocks didn't show that they were to be six inches?

A. I can't.

Q. When, and how, did you first discover that the braces had been put in wrong?

A. I was advised that the bridge was going on very slowly, and having some trouble in raising it—didn't come together right; and I went down myself to see what the trouble was, and there discovered it.

Q. Was not that after the bridge had been raised, and, when let down on its own weight, it was found to be unable to sustain itself?

A. They had been to work at it for some time. It was not raised; they had been to work at it, and found trouble in raising it. When they were changed, I heard of no further trouble.

Q. You are not sure, then, that the change was made before the structure was raised finally?

A. Yes, I know it was.

Q. Who was intrusted with the supervision of putting the bridge in place?

A. My impressions are that Mr. Tomlinson started it. But he was so inefficient that I discharged him, and the work was then put into the hands of Mr. Rogers.

Q. What experience had Mr. Rogers in that kind of work?

A. How many years, I don't know. He had experience in raising constructions.

Q. Had he ever put together an iron bridge before?

A. I don't know as he had.

Q. Or since?

A. I don't know. No, sir.

Q. When you made the inspection yourself, did you not discover, also, that some of the main braces had been used for counter braces and some of the counter braces been used for main braces by Mr. Rogers in erecting the construction?

A. I don't recollect that. Some of the counter braces and the main braces are nearly alike, and might possibly have done so. That is the only error where that could be made. It would be impossible to bridge it any other way.

Q. If the lugs had been clipped off, and changes made, what was there to hold the braces in position?

A. The weight and pressure of the bridge coming together, bound by the vertical truss-rods, would hold in place.

Q. Would not the least change of the truss-rods allow the braces to slip out of position, if there were no other fastening than their merely raising on a plain surface in the brace blocks above and below?

A. The unscrewing of a rod from its bearing would loosen them.

Q. In twenty feet of brace, set in a panel of eleven feet, how much would the rods have to be lengthened to allow it to drop out, if the brace blocks were plain?

Q. By Mr. Burns: With the lugs chipped off?

A. An eighth of an inch would allow a counter brace to move; letting down an inch wouldn't move it at all. The bridge would gradually come down to the edge.

Q. By Mr. Converse: Would the dropping out of one or two counters effect the structure of the bridge?

A. It would not.

Q. How many counter braces could be dropped out of that bridge without its crushing?

A. My impressions are, if half of the counter braces were out of place, it would not effect it.

Q. What, then, was the necessity of putting in counters at all?

A. It enables the bringing of the bridge to a perfect bearing, and to receive a shock of a train at the highest speed.

Q. Do not the counters serve the purpose of carrying a large load to the further abutment from the load; and for that reason are they not absolutely necessary to the bridge?

A. As you go to the centre of the bridge, the counter becomes a main brace. Near each end of the bridge they have but little service to perform, otherwise than to receive a shock, as a train may strike it.

Q. If these counters were to drop out near the center of the bridge, would it not effect the structure of the bridge?

A. If they should drop out to a large extent—if several of them dropped out of place, it might.

Q. Would it not, in your judgment, if the bridge should carry a weight of three hundred tons above dead weight, result in the destruction of the bridge?

A. No, sir; you may examine any old bridge that has been up for a series of years, and that has never been screwed up, you will find two-thirds of the counter braces loose in that bridge. These matters, however, I speak of. I suppose you don't take note of this. This is not my testimony.

Mr. Converse: I think he is taking everything. (The reporter.)

Witness: I give you that, having been an old bridge-builder. I give you the information.

By Mr. Converse: It is important.

Witness: It can be proved, by finding yourself the facts, in any old wooden bridge.

Q. Why was not some other means designed and provided for to hold both the main and counter braces in their old places, after the lugs had been chipped off, in changing the bridge?

A. The lugs were put on more for convenience in raising; the supposition being that the strain put on the braces, with the use of the screws, would bring so heavy a friction upon them that there would be no occasion for any lugs.

Q. I will ask you, sir, whether it is not the universal practice to provide some means for the holding of these braces in place?

A. Not that I am aware of.

Q. I will ask you, sir, if the authorities, without exception, don't require some means to be provided for holding these braces in place?

A. They were held by clamp bolts, at intersections. I suppose that would be sufficient to keep them in place.

Question repeated by Mr. Converse.

A. I am not aware of such.

Q. Can you name a single authority who states that it is not necessary to provide other means than the mere pressure, such as lugs, etc.?

A. I never noticed an allusion to it.

Q By any of the writers?

A. No, sir.

Q. If one-eighth of an inch in the lengthening of the tie rod allowed the counter to drop out, wouldn't it require some provision to be made to hold them in place?

A. The tie rod would not elongate an eighth of an inch unless it was too weak for this purpose, as they are tightened up five or six feet with a wrench, and intended to put upon the rod a much greater strain than the load itself.

Q. What was the lateral bracing between the lateral chords of the bridge?

A. [Examines paper.] Two and one-half by one-half inch.

Q. Flat bar?

A. Yes.

Q. How near together were they placed?

A. I don't recollect the number.

Q. Were they not at every other panel?

A. The panels might have been twice as long as the other panels, and they came together directly through the entire length of the bridge; they intersected each other; I mean, in other words, there was no place but where there were lateral braces.

Q. The question which I put was, were they not simply at every other panel?

A. No, sir.

Q. Of the truss?

A. They were not at every panel; but the panel might have been longer than the vertical panels.

Q. Were they not twenty-two feet from these lateral braces?

A. In other words, you ask whether the panels were not twenty-two feet longer?

Q. No, sir; the brace in the lower chords?

A. No, sir.

Q. What distance were they?

A. They came together.

Q. How do you mean come together?

A. I will make a diagram. [Diagram made and shown to committee.]

Q. How far apart were the struts, between the lower chords of the bridge?

A. The struts where the diagonal braces were attached, do you mean?

Q. Any of them.

A. I don't recollect that; they might have been twenty-two feet.

Q. Now these rods, that you speak of as braces, two and one-half by one-half, were they not simply ties, instead of braces? Was it not tension employed, instead of compression?

A. Yes.

Q. Will you explain what effect such a compression and tieing would have upon the lower chords of a bridge; is it not an element of weakness which would give it no strength whatever?

A. No, sir; on the contrary, it was on the principle of a perfect truss as applied would act, for the purpose designed.

Q. Let me ask you this question; whether these ties, that you speak of, didn't cross each other in the center of each of these lateral struts through the lower chord?

A. It is possible; but there were struts where the braces intersect at the chords.

Q. Are you sure on that point?

A. Yes.

Q. Have you a photograph of the bridge taken by the company?

A. Yes.

Q. Is it here?

A. Yes.

Q. Will you examine it and see whether you are not mistaken?

A. I don't think it will show that feature; those bottom laterals had but very little service to perform; the bridge would be very safe, even without any laterals there, it was so very thick.

Q. Would not the tie bars, bearing tensile strains, as you have stated, draw the lower chord nearer together? [Photograph of bridge referred to.]

A. No, sir; the whole weight of the bridge draws the trusses; there is great strain upon the chords, and makes them very stiff.

Q. Would it not have been much stronger if the tie-rods had been fastened to each of the brace blocks, so that the panel in the lower ends would have been of the same size as the panel in the chord?

A. That wouldn't have made material difference, unless the bar was larger.

Q. What was the size of the bridge?

A. I have known bridges to be erected———

Q. What was the size of the strut between the lower chords?

A. That I don't recollect. My impressions are, T rails.

Q. Will you explain to the committee how the track and ties were supported on the bridge?

A. There were three seven-inch beams to each panel; under each rail there were three stringers, bolted together, lapping each other, six by thirteen inches or six by fourteen, I am not certain which. In addition to that there were two other stringers, I think the same size, near the outside of the bridge, upon which there were, when the bridge was constructed originally, three-by-four cross-ties spiked on to those stringers, on which the rails were.

Q. How were these iron cross-ties fastened to the upper chords of the bridge, if fastened at all?

A. My impressions are that they were fastened by loop bolts passing over the beams and then fastened underneath the top chords, the nuts resting upon the washer.

Q. How many of those beams were there to a panel, did you say?

A. Three.

Q. Please state whether or not the resting of those iron rails upon the top chord in the centre of the panel would not weaken the upper chord?

A. I don't think they would.

Q. Was it usual to have those beams resting on the top chord between the panels in the strongest bridges?

A. It has always been done; yes, sir.

Q. What is the purpose of the upper chord? and what is the strain put upon it? What is the nature of the strain put upon it?

A. The nature of the strain of the upper chord is that truss (referring to photograph).

Q. In the carrying of live weight on the girder in the centre panel here, and straining in a different direction, don't it tend to weaken the upper chord?

A. It has always been regarded to be so minutely as to have no account taken of it.

Q. Isn't it usual to place these cross-beams to strengthen the panel?

A. The top chords are designed to be strong enough to do the duty.

Q. What was the size of the top chord?

A. Four-by-seven inch beams—five of them—parallel.

Q. What shape?

A. T.

Q. What was the size of the flange?

A. One-half inch thick, I think, by four.

Q. What was the size of the web?

A. One-half inch.

Q. Will you be kind enough to take your pencil and give us the surface of the iron on that chord, and tell us how much strain it will bear?

A. I wish to correct the size of the webs. The top chord varied from one-half inch up to one inch in thickness, being thicker in the middle and lighter at the ends.

Question repeated.

A. Three hundred and seventy-five tons.

Q. How much do you calculate to the square inch in that?

A. Thirty-five thousand pounds.

Q. How many inches of surface do you make each of the stringers?

A. Top chords?

Q. Yes.

A. Two hundred and ten inches.

Q. Not in each stringer?

A. Yes, sir—I beg your pardon—no, sir. I am mistaken about that. Fifty-two inches and a fraction over.

Q. How much, then, would that be? What would be the resistance—fifty-two inches, divided into five bars—which you had in the upper chord to resist?

A. Possibly the pressure of nine hundred tons.

Q. Was not the dead weight of this bridge near five hundred tons?

A. No, sir.

Q. What was the dead weight of the bridge, as you remember it?

A. My impression was, something over one hundred tons. I don't recollect just exactly, but you must bear in mind there were two trusses.

Q. Do you remember what the dead weight was per lineal foot?

A. Of the bridge itself?

Q. Yes; including cross-ties and tracks.

A. It wouldn't be far from a ton to the foot run. That may not be accurate.

Q. Could it be as much as three thousand two hundred pounds to the foot?

A. That bridge?

Q. Dead weight.

A. I think it could not. One thousand six hundred pounds to the truss, you mean. I think it was not as much as that.

Q. How far apart were the two tracks that went over the bridge?

A. Seven feet.

Q. How near perpendicular above the truss would that bring?

A. It would bring one rail upon each truss.

Q. By Mr. Burns. The outside?

A. The outside rail of each track would be over each truss.

Q. By Mr. Converse. The outer edge or inner edge?

A. It would bring the centre of each rail near the centre of each truss—the outside rail near the centre of each truss.

Q. Would not the bridge have to be nearly twice as strong to carry two tracks in that way than what would be required to carry one track in the centre?

A. Yes, sir; twice as strong.

Q. With the strain of nine hundred tons on the upper chords, a dead weight, and the added weight of a loaded train and two locomotives, you may state to the committee whether that wouldn't produce the strain nearly to the capacity of the iron in the upper chords?

A. I think we are mixed in that a little. Did you understand me to say that the bridge had a strain of nine hundred tons?

Q. Was capable of bearing nine hundred tons. I will change the question. If you allow a dead weight of three thousand two hundred pounds to the foot, wouldn't then a loaded train going on one chord on one side of the bridge strain the chord nearly to its capacity?

A. I have carefully considered the matter. With its dead weight, which alone wouldn't strain any portion of that iron, even with two trains upon it, to exceed from eight to nine thousand pounds to the square inch, while it was capable of resisting thirty thousand pounds to the square inch.

Q. Would not that one train on one side of the bridge strain it as much as two trains, or nearly so?

A. It would strain the truss passing over about eighty-five per cent., or as much as it would were two trains passing over at the same time.

Q. It is stated that when the bridge broke the bridge swung to the north, while the load was pitched off to the south. Can you give us any explanation upon that point—why it was so?

A. It is very conclusive evidence, to my mind, that the bridge was carried down by the second locomotive in some way leaving the track. The bridge was not strong enough to take a locomotive across off the rails. Had the bridge broken through weakness it would have pulled in the other direction. I understand you to say that the bridge swung to the north?

Q. Yes.

A. Had the bridge broken from its own weakness, it is conclusive to my mind it would have swung to the south. I am convinced, a model test, to the extent of breaking a truss, would show conclusively that that truss would fall to the south and pull the bridge to the south. An engine dropping on the cross floor beams would tend to deflect them and pull the truss inward—that is, the truss to the north, that the train was passing over on, and when pulled to the north from a vertical line to a small extent it would go down.

Q. You stated a while ago, that the braces were fastened together in the centre—will you explain how they were fastened, and the effect of it upon the bridge?

A. They were fastened by loop-bolts through the yokes, which done, would keep them all in place.

Q. What was the size of the loop-bolts?

A. I am not certain whether it is three-fourth or seven-eight of an inch—I have no means of knowing.

Q. Would either be sufficient to strengthen to any considerable extent the braces?

A. It adds to the security of the braces in keeping them in line. A brace twenty-one feet, without intermediate support, would hold a floor less than with the support at the middle brace—in other words, it is like a column twenty-one feet long, compared with one half that length.

Q. Would not this bridge have been stronger if your tie rods had been oblique and the braces perpendicular?

A. Not as strong.

Q. Does not the strength of the brace decrease in proportion to its length?

A. Unsupported it does.

Q. Whether supported or not, does it not?

A. The tensile to the rod, is diminished in strength in its carrying capacity, just in proportion as the distance is longer on its angle then it would be vertical. This system makes the compressive members ten feet, nine inch long—while on the system that you suggest they would be nineteen and one-half feet long, therefore, they are made stronger by being arranged in this wise.

Q. Is not the only support imparted to it, the strength which the counter brace, bearing laterally in the middle?

A. Each one have to support the other—all bind together. It would be impossible to crowd them out of line, therefore, every one of the counters and braces tend to support each other. I have constructed from ten to fifteen miles in length of Howe bridges.

Q. Have you constructed other bridges on the Howe plan with wrought iron braces, as in this bridge?

A. I have not.

Q. Do you know of another bridge?

A. I do not.

Q. Any where?

A. No.

Q. When you found that Mr. Rogers had put a brace in wrong on the first putting up the bridge, do you think it was negligence in again trusting him with erection of the structure?

A. No, sir; I think it was not. He couldn't put the work together different than what I designed it.

Q. Do you think it was wise to entrust him with the erection of the bridge after that?

A. I do.

Q. What was the size of the ties reaching from on chord to the other—the sway rods?

A. One and a quarter inches in diameter.

Q. How far a part were they?

A. Each panel eleven feet a part.

Q. Were there not twice that?

A. There were twenty-eight used—that would be right at fourteen panels.

Q. How were they fastened to the chords above and below—how were they drawn together?

A. I don't recolleet exactly.

Q. Would it be bad workmanship if in cutting of the threads upon these iron the size was reduced to three-quarters of an inch where the size was an inch and a quarter?

A. Yes, sir. From an inch and a quarter to three-quarters.

Q. Have you examined these rods to see whether they were materially reduced at the there ends?

A. No, sir.

Q. How would it be to reduce to five-eighths at the thread ends?

A. From an inch and a quarter?

Q. Whatever size they were.

A. It wouldn't be a good job, as I will state in this connection. My directions there was carried out. The vertical rods were enlarged so that the inside thread was the same diameter as the nut itself.

Q. I am speaking only of the sway roads.

Q. By Mr. Burns: That was your direction?

A. All the vertical rods were made in that way so as to give the bolt the same strength.

Q. By Mr. Converse: Did you make a statement how they were fastened?

A. I don't recollect.

Q. What was the size of the braces originally projected to be put in the bridge and the counters.

A. Seven inches T beams.

Q. The flanges four inch?

A. Yes.

Q. And the web seven?

A. Yes.

Q. What is the thickness of the flange and web?

A. The counters were three-fourth and the main brace three-four web.

Q. How was the flange?

A. I can't give the exact thickness—the usual thickness of T beams.

Q. Can you give us some idea, so as to make our calculation upon that subject?

A. My impressions are, about one-half of an inch.

Q. How many of these beams were designed to be? And state whether they were varied in number, as originally planed, as you approach the centre of the bridge.

A. The first portion was supported by six abreast.

Q. As originally planed?

A. Yes; and they diminished to three abreast from the middle panel, the other two being counters. There was used at the bridge five braces in each panel, and at the ends, six main braces.

Q. How much less in size were these beams finally made?

A. I don't know.

Q. Are any of those beams seven inches now by four?

A. I understand them to be; they may be a fraction less. I understood it to be the way I have given.

Q. If there were six at the end of the bridge, was it not after the bridge was re-built when five were put in at the end of the bridge, diminishing to the centre?

A. My impressions are there was six put in. The bill shows that there were put in six at the end panels, full length, and five at all the other panels. There is five at every panel. In some panels there are four main and one counter. And others, in the middle, there are three main and two counters. And at the end there are six main braces, and near the end, four main braces and one counter.

Q. Was there not some trouble in finding rolls as originally projected?

A. Not that I know of.

Q. Had you any interest in the rolling-mill where they were designed?

A. At that time, not a dollar.

Q. How long before, or after, did you have, and who were the owners at that time?

A. I was not an owner until I left the charge of the road. The heavy stockholders were Chisholms, Jones, and my brother. I don't know who the other one was.

Q. What is your brother's name?

A. A. B. Stone. The firm name was Stone, Chisholms & Jones.

Q. I will ask you who was the superintendent of that part of the road last year?

A. The general superintendent, Charles Payne; the division superintendent was Mr. Couch.

Q. Whose duty would it be to see to the bridge, and to examine it from time to time?

A. The duty of Charles Collins, the chief engineer, generally; who he relies upon to do that duty, I don't know.

Q. Ought not such a structure as that to be examined every few days, while in use as such a company as the "Lake Shore?"

A. The bridge had stood a dozen years without showing any defect or weakness; they would not be likely to examine it as often.

Q. I am only speaking what prudence would require.

A. That would be extraordinary caution, more than is given to structures.

Q. How often would, with ordinary care, with the amount of travel on it, ought it to be examined?

A. If done by bridge men, experienced men, as often as three months, thoroughly, and then, by the track men, quite frequently.

Q. Would there be any necessity, from time to time, to tighten up the nuts and again loosen, on account of the temperature of the weather?

A. Would not; the nuts are practically as tight in warm weather as in cold.

Q. This examination, then, ought to be made for the purpose of observing whether any thing has given away in any part of the structure—whether any nuts are loosened, and things of that kind.

A. Yes, sir.

Q. Why was it that the cars, and the people in them, were burnt up after this accident? What was the cause of it?

A. No doubt it might have been done from the locomotive, or from the stoves in each car.

Q. The locomotive, as I understand, was down in the bottom of the stream.

A. That might have been; it is probable, then, that the fire took place from the stoves.

Q. Why didn't your company comply with the statute of the State, requiring stoves to be put in that would not do that in case of an accident?

A. I examined those stoves, and it was said they would not cause fire; my conclusion was that they were more dangerous than the ones we used—that there was no safety about them any more than any other stoves.

Q. Why didn't you heat the cars by steam from the locomotive?

A. It isn't practicable; no engine can furnish enough steam for its regular work and to heat the cars also. The work of breaking with steam comes when the train is slacking up, and the steam for running the train is not in use.

Q. Your opinion is, then, that no stoves could be provided that could extinguish a fire in case of an accident.

A. No, sir.

Q. And that is the reason that your company made no effort or made no change in the stoves?

A. Yes.

Q. It has been stated that since this bridge fell that when the bridge was first completed that it couldn't bear its own weight. Do you know any thing about that?

A. I never knew anything about that. I knew there was some trouble in raising. When I found out of their being delayed in consequence of that, I went down and found the only thing wrong about it was putting the braces flatwise instead of vertical; and since that was remedied I never heard any other thing not put in right as originally designed. I never heard any difficulty about it. That did cause trouble. They were not designed to go that way, and it would cause trouble in raising the bridge. As soon as that was remedied there was no trouble.

Q. Then you didn't have to change the original plan after that was arranged?

A. No, sir.

Q. Mr. Burns: Mr. Stone, what, if any, examination or practical test of the self-extinguishing stoves have you seen made?

A. I was called upon to see a self-extinguishing stove at one time, when I was president of the road, and in my judgment it was of no importance—it was of no advantage with fires carried upon cars. It is impossible.

Q. What stove was that?

A. I don't recollect the patentee's name. I have forgotten the patent. I have seen two or three designs. I have only a general impression, because it didn't strike me favorably at all of being any advantage as a practical stove.

Q. Mr. Brunner: Did you ever see the Winslow stove?

A. I think that is the one that I saw. (Circular shown to witness.)

Q. Mr. Converse: One is for wood and the other is for coal?

A. I never saw the coal, I saw the wood. This, in a certain way, will put out the fire, but I don't think it is a practical stove.

Q. Mr. Burns: Have you any recollection, Mr. Stone, of having said to any one, or more than one, when the Ashtabula bridge was referred to, "that wasn't a good brige; it wasn't built as you would indorse; you didn't indorse the bridge fully after the bridge was built?" And did you make an expression like this, "that is not my bridge?"

A. I never said it, and I never thought it. I never shirk responsibility. At the time we erected the bridge we was making the road very perfect, and put up what we thought there a very perfect bridge. A better bridge would have been, probably, a stone bridge, or arch. At that time we had determined what funds we had to expend, as we were short. We designed this to be a first class bridge.

Q. Mr. Converse: When the braces were taken out and put in as "I" braces, were the corners not clipped off and the section surface of the braces very much diminished?

A. The corners were clipped off in some cases, but in no case, in my judgment, to weaken the structure one particle. There was still left a much greater strength at the ends than there would be in the middle; and very often you will find iron reduced one-third at the ends from their sectional size in the middle, and still have more strength in the ends than at the middle. They would cripple before they would crush.

Q. Isn't it, on many of those flanges, clipped away for an inch and a half?

A. No, sir.

Q. I don't mean square inch, I mean flange?

A. No, sir; if one-fourth of the entire area was reduced it wouldn't weaken the bridge.

Q. Well, when the bridge was going up, did you give your personal attention to it?

A. No, sir.

Q. Did you employ any skilled engineer, or instruct the man to make an experiment with the bridge, or examine it, or superintend it?

A. The iron work was done by as thorough a master machinist as I know of. And when he worked at the plans that was all there was of it. And when the bridge was tested I was present, with a very heavy load.

Q. How often were you there while it was being erected—put up?

A. I was at the shops frequently and examined the parts as the machinists were making them. But during the erection of the bridge I don't think I was there but once.

Q. Did you go there at all until you were sent for by Mr. Rogers, stating that the bridge had settled nearly six inches, taking the camber off at the time?

A. I never heard of any such report as that. I heard there was some difficulty about the braces. I think I was present at the bridge soon after commencing to raise it, and then when it was reported to me about its not coming together I went down to see what the trouble was.

Q. Did Mr. Collins bring you the word, when you went down?

A. My impression is that he did, but I am not certain, however.

Q. You were there, then, only the once?

A. I think I was there twice. I think I was there three different times. I was there when they commenced raising it, and when the trouble was reported to me, and then when it was tested—there at least three times; and my impression is four times. When the test was made it was stiffer than I supposed.

Q. Mr. Wilstee: If a train be passing over the bridge at the rate of ten or fifteen miles per hour, and the air breaks be applied, what effect would it have?

A. It would throw a strain upon it, but very small.

Q. Mr. Brown: What, in your opinion, was the probable cost of building that bridge, with stone archers?

A. We had it figured at the time, but I have forgotten what they were—not to exceed $15,000 at the time.

Q. This present bridge is estimated to have cost $75,000 or $80,000?

A. That is a mistake. The iron bridge cost—I don't know what it cost—my impression is that it cost $15,000. The iron bridge and masonry cost, possibly, what you said.

Q. We got the impression that it was the iron bridge itself?

A. That is a mistake. I think it cost not far from $100 per foot. It might possibly be more. Iron was very high then. I can't state positively, but not less than $100 per foot.

Q. The building had stone arches, that's what brought it up?

A. Yes. My impressions are that estimate was in the neighborhood of $100 or $115 per foot. Mr. Collins may have the data that he had before us at the time.

Q. Mr. Converse: What would be the effect upon this bridge if a loaded train, with two locomotives, running on it on the south side, and the wind blowing from the north, if one or all of those sway rods were to break—how would you expect it to act under such circumstances.

A. With sixteen lines of timber from end to end, as they were, and fastened as they were, covered from end to end with ties, fastened from side to side to the bridge, my judgment would be that, together with the great thickness of the truss, which is twice as much as any other bridge, as you would find, that it would be an extraordinary wind that would affect it at all. If there wasn't lateral bracing—

Q. Sway rods?

A. Sway rods. That, take two in between them abutments, the way it was fastened, would present a very strong lateral strength.

Q. Would or would not a wind blowing from the north put a strain upon these sway rods?

A. A certain strain upon them, but the trusses themselves have double the lateral stiffness of any truss upon an iron bridge that I know of.

Q. The upper chord was bolted every five feet?

A. I think so.

Q. Will you state to the committee whether that mode of fastening the beam and the upper chord together was not an element of weakness?

A. I will state that it is an element of strength.

Q. Didn't weaken the chord in fastening them in that way?

A. The upper chord?

Q. Yes.

A. No, sir.

Q. These bolts that went in these five feet, they were not turned bolts, neither were they put in hot, to fill the holes. So far as the resistance of compression was concerned, wouldn't it have been the same as if the hole might have been empty?

A. These hole were made—the surplus strength was more than four times, according to my calculation, what would be required in rods. Clamps were used on the bottom chords to prevent tension.

Q. Can you get for us the original plans and specifications?

A. Well, Mr. Newell or Mr. Collins; they can be got in that way from Mr. Newell or Mr. Collins, if they have it. I don't know. I havn't seen it. If you should not succeed in getting it I will be willing to do anything that I can. You are right near the office.

EXHIBIT.

Bill of Iron for Ashtabula Bridge.

C P. & A. R. R.—July 20, 1863—*Ashtabula Bridge.*

12	I beams	for top chord,	21 feet	10 inches,	with	1	inch neck.
12	"	"	"	"	"	7/8	"
20	"	"	"	"	"	1/2	"
12	"	"	"	"	"	3/8	"
8	"	"	25 feet	10 inches,	"	5/8	"
16	"	braces,	21 "	7 "	"	3/4	"
32	"	"	"	"	"	1/2	"
86	"	"	"	"	"	3/8	"

42 I floor joists, 20 feet, 1/2 inch neck.

2	bars	B iron,	5 by 1 3/8,	55 feet		10 1/2	inches.
6	"	"	"	47	"	1 1/2	"
10	"	"	"	43	"	10 1/2	"
22	"	"	"	43	"	9	"
4	"	"	"	42	"	3	"
2	"	"	"	39	"	6	"
4	"	"	"	36	"	3	"
4	"	"	"	30	"	9	"
4	"	"	"	25	"	7 1/2	"
2	"	"	"	19	"	9	"
4	"	"	"	19	"	7 1/2	"
4	"	"	"	17	"	6	"
4	"	"	"	12	"	0	"
52	"	"	"	2	"	0	"

50 feet B iron, 5 by 1.
116 pieces " 3½ by ¾, 2 feet 2 inches.
32 bars " 2⅛ 0, 21 feet.
32 " " 2 in. 0, 21 feet.
48 " " 1⅞ 0, "
32 " " 1¾ 0, "
48 " " 1⅝ 0, "
16 " " 1½ 0, "
12 " " 2 in. 0, 11 feet 6 inches.

C. P. & A. R. R. Co., additional bill of iron for Ashtabula Bridge.

28 diagonal braces, 15 feet, 1¼.
28 " " 12 " 1¼.
12 top and bottom lateral, 28 feet 7 inches, 2½ by ½.
10 end " " 21 " 2½ by ½.
28 washers, 4 feet 1 inch, 5 by 1.
76 " 3 " 9½ " 5 by 1.

August 5, 1863.

Above copied from Cleveland Rolling Mill book marked "Back Orders;" also, the following:

C. P. & A. R. R., for Ashtabula Bridge.

8 bars, 5 by 1⅝ iron, 26 feet each.
March 17, 1864.

C. P. & A. R. R. Co.—Congden.

8 bars, 5 by 1½ iron, 25 feet.
July 8, 1864.

TESTIMONY OF CHARLES COLLINS.

Charles Collins, being duly sworn, testified as follows:

Q. By Mr. Converse: What is your full name?

A. Charles Coilins.

Q. Where is your place of residence?

A. Cleveland.

Q. How long have you resided in Cleveland?

A. Most of the time since 1850, with the exception of about two years I have been away, but constantly since 1859.

Q. What relations do you sustain to the Lake Shore Railroad Company?

A. I am the engineer and purchasing-agent in my department.

Q. What section of the road have you charge of as engineer?

A. The entire line.

Q. You may state what points?

A. From Buffalo to Chicago, with the branches.

Q. How long have you held that position?

A. Since 1859, but not on the entire line. I have held the office on some part of the line.

Q. What relation did you sustain to the company at the time of the so-called Ashtabula bridge was built?

A. The same as I do now.

Q. What year was that erected in?

A. It was commenced in 1863, and finished in 1865, to the best of my recollection.

Q. Did you reside any portion of that time at Ashtabula?

A. I was there a portion of the time, but my home was here.

Q. How long had the bridge been built that was used before this one—before the one that was wrecked on the 29th of December?

A. It was built in 1852, and was used up to the time we commenced to use the iron bridge in 1865. I believe it was 1865. I am speaking to the best of my recollection.

Q. Where are the plans and specifications to that bridge?

A. I do n't know, sir.

Q. Do you know where either of them are?

A. No, sir. Nothing more than the plan that was before the jury at Ashtabula. I suppose it is the same.

Q. Was that the original plan?

A. It is the only one that I ever saw, sir. From the date on it, I should judge it was an original plan—a general plan.

Q. Were there any specifications accompanying the plan?

A. This plan? No, sir, not to my knowledge.

Q. Is n't this plan that you speak of a full plan of what is known as the working-plan?

A. No, sir.

Q. Were there not working plans made?

A. I suppose there were.

Q. What became of them?

A. I don't know.

Q. Did you ever see them?

A. No, sir; I have no recollection of seeing them.

Q. Why are not such things preserved by the company?

A. They are generally, sir; but this seems to be an exceptional case in every particular.

Q. When did you first discover that these papers were absent from your office?

A. They never were at my office.

Q. Did n't they belong at your office?

A. They should have belonged there.

Q. Why were they not, then, at your office, if they belonged there?

A. The reason is this: About the time this bridge was commenced, or before, the Cleveland, Painesville, and Ashtabula Railroad Company sought to get a line from Jamestown to Franklinton. They imposed that duty on me. When they done that, the president of the road says: "You have so much to do with the Ashtabula bridge, I will get a bridge-man for the Ashtabula bridge, and we will relieve you entirely." That is the reason, sir.

Q. When did you make search for the plans and specifications, if you ever made any?

A. I never saw the plans or specifications—that is the working plans. The plans were inquired for in my office, and the clerk searched for them and could n't find them.

Q. When was that?

A. That was since this calamity.

Q. So far as you know, the plans and specifications remained with the president of the company?

A. Yes, sir. I think, sir, they were up at the shop where the bridge was constructed—where the work was done. They would naturally want the working plans there.

Q. Would n't they naturally want the working plans and specifications where the bridge was to be set up afterward?

A. Yes, sir, I suppose they would.

Q. State whether the examination of this bridge came under you as an officer of the company.

A. The examination of the bridge? Yes, to parties under me. They were working under my direction.

Q. Why should it belong to them, instead of yourself, to see if it were done, if you were engineer?

A. I could n't inspect all the bridges myself. I have got to trust somewhat to men. My instruction to men is, if there was any point they were in doubt, to consult me.

Q. You did authorize them?

A. Yes.

Q. When did you authorize and direct to make the examination of them, and when?

A. G. M. Reed is the head of the department.

Q. When was he directed to make an examination?

A. He has no specified time to make examinations. Whenever at such times as he thinks it is necessary.

Q. I understood you a moment ago that you directed the examination to be made whenever you thought it was proper?

A. They have a general order. I would like to explain a little further about the organization of the bridge men and carpenters before the consolidation. For instance, from Baffalo to Erie, from Erie to Cleveland, Cleveland to Toledo, each of those divisions had a bridge gang and a carpenter, who took care of the bridges. After the consolidation, that organization remained the same, and to it was added this general bridge man or superintendent of bridges.

Q. When did this Reed, who is charged with this duty, make a report to you in relation to this bridge?

A. In September, I think.

Q. What report did he make then?

A. It was right.

Q. It was in good condition?

A. Yes.

Q. Was that report made in writing, or verbal?

A. Verbal.

Q. Is it the habit of your company to direct its officers to make examinations, and simply make verbal reports, or are they required to be in writing, so as to be placed on record?

A. They are not required to be in writing, the ordinary daily business of the road.

Q. How often did you direct that bridge to be examined?

A. Never had any specified time; he was directed to keep up the inspection properly.

Q. Did he not have instructions from his superiors, in the line of his duties, as to when and how the examination should be made?

A. There was no time specified.

Q. My question was, "How often;" not as to specified time.

A. That was in his judgment.

Q. What business, or duties, had you to perform, then, as chief superintendent, or engineer, which ever it was, if you could simply appoint your subordinates and rely upon their judgment as to what was to be done without any written report, or anything else?

A. My instructions to him was, if he found anything that he was not satisfied with, or wished counsel, to call upon me.

Q. Does it not strike you that that is a very loose way to do business, with such vast interests, and property, and men's lives involved?

A. No, sir; I thought everything was well taken care of.

Q. By Mr. Collins: I will ask you whether you ever made a statement to various persons, in relation to this Ashtabula bridge that was wrecked, "that you were not responsible for it; that you didn't want the public or anybody else to understand that you were responsible for it; that it was Stone's bridge, and that you never had, or would have anything to do with it?

A. It is a mistake.

Q. Did you make any statement in that direction?

A. No, sir.

Q. I will ask you, if Mr. Rogers called upon you when the bridge was settling down, and asked advise of you, and whether you declined to give it, as officer of the road?

A. I was staying at Ashtabula over Sunday, and he came to my house on Sunday and wanted me to go down to the bridge with him: I never had been there to see the work, and didn't wish to interfere with it, and declined. He asked me as a personal matter to go, and I went.

Q. Did he ask you what should be done in the matter, or what he should do, and did you decline to give him any information?

A. I said to him, sir, that the braces were in wrong; they got them in flat, instead of on the edge, in my opinion; but I have no directions to give in regard to it, as I had nothing to do with it; I may have said that the president, or Mr. Stone, should attend to this bridge matter—that is, the bridge matter.

Q. Did you say to Mr. Rogers that you would notify Mr. Stone, and have him come down and see about it?

A. He requested me to ask him.

Q. Did you do so?

A. I did.

Q. How soon after that?

A. This was Sunday, and this was on the following Monday morning, I think.

Q. Were you there when Mr. Stone was there?

A. Mr. Stone invited me to go, and I did.

Q. What did you discover as to the condition of the bridge, when you went with Mr. Stone?

A. Mr. Stone remarked that the braces were wrong; he was very much surprised to find the braces in that position, and it was wrong, and not as he designed.

Q. I didn't ask you what Mr. Stone remarked; I asked you what you discovered; that is what I want to know.

A. I discovered nothing more than that the braces were not in a proper position.

Q. Was the structure then up, and resting upon the trestle work?

A. I think it was, sir.

Q. Had the wedges been pushed out from under it, to see if it would settle a little?

A. Standing in that condition, at that time, I couldn't tell you, sir.

Q. How much had it settled at the time you went back to look at it with Mr. Stone?

A. I don't know.

Q. Was there any counter brace in that bridge at that time?

A. I don't know.

Q. Was it still resting upon the trestle?

A. I think it was; that is my recollection.

Q. Well, you may state whether any directions were given to Mr. Rogers that day in relation to that bridge?

A. I don't know what directions were given.

Q. Will you be kind enough to state whether Mr. Stone didn't return to Cleveland, stating he would think the matter over, and would give him directions in a day or two?

A. He went to Cleveland that day, to the best of my recollection.

Q. Do you know how soon he went back again?

A. I don't know.

Q. How long after the first visit?

A. I couldn't fix the time.

Q. About how long?

A. My recollection is very poor upon that; I don't know.

Q. What was the progress of the bridge in the erection at the time you went back the second time, from what it was when you were there in the first place?

A. I think it was completed. I think I wasn't there again until it was.

Q. Was that at the time it was tested?

A. Yes.

Q. Do I understand you to say that you never mentioned to any one that this bridge was not yours, and you didn't desire to have the responsibility of it in any manner?

A. No, sir; as I stated before when asked about it, I declined to have anything to do with it, from the fact that they had appointed some other man to build that bridge and take care of it; and therefore I declined to have anything to say about it, and might have remarked that it was Mr. Stone's or the President's bridge, and I didn't wish to interfere.

Question repeated.

A. I have no recollection of using that language, or anything of the kind.

Q. Do you know what changes were made in the bridge after you found it on the braces when you visited it with Mr. Stone?

A. I know of one change that was made then. What others were made, I don't know.

Q. State what they were.

A. That was in turning the braces, and putting in an additional number.

Q. How many were put in, in addition to what there were there when you visited it with Mr. Stone?

A. I don't know, only in the first set of braces.

Q. How much was the increase in the first set?

A. Two in each set, I believe.

Q. Clear through the whole bridge?

A. No, sir; that is in the first set of braces after that.

Q. Two on each side, is it?

A. In each additional brace there was an additional two, making eight; that is to the best of my recollection.

Q. How soon after the structure was erected was it that it came under your care as engineer?

A. I don't know; I can't recollect. It was the time of the building of the second track was in progress; at the same time in making the fill from the old fill to the new; it was some time in 1866; I will not be positive as to the date.

Q. Did you ever make an inspection of that bridge yourself?

A. Yes, sir.

Q. When was the first?

A. Soon afterward. I was in it when the train went over it, and passed through it.

Q. Did you make any further inspection of it than simply in it when the trains were passing over it?

A. I looked over it at that time.

Q. Did you look at it as an engineer, to see whether there was any weakness, or anything wrong about it?

A. I noticed it.

Q. In the examination, what did you find in the bridge to hold the braces in position on the brace blocks?

A. There was the yoke around the center and the casing on the side of the angle blocks.

Q. Were they not all chipped off?

A. Not all.

Q. When the additional number was put in?

A. No, sir, not all.

Q. Well, the lugs, were they not nearly all chipped off when the change was made in the bridge?

A. I think not, sir.

Q. How many of them?

A. I couldn't say, sir.

Q. If you examined the bridge, why did you not examine that point to see whether those lugs had been clipped, and to see how many remained.

A. I didn't see any trouble in the braces when the bridge was fixed.

Q. You knew that some of those lugs had been chipped off when you made the inspection. The question which I put is, why didn't you make the examination, and know just how many there were, and just what there were to hold these braces?

A. I didn't notice there was anything to effect in any way material. I didn't suppose the braces would get out of position.

Q. Was there anything to hold it except this little support in the center—five-eighths——

A. That is the main thing, I suppose.

Q. Would you regard that as any material strength in the construction of a bridge to hold large braces in position—seven-eighths clasps around the center?

A. Yes, sir, I should, sir.

Q. Was it sufficient, then?

A. I never knew anything to the contrary.

Q. I will ask you as an educated engineer, who is supposed to know all about this subject. I want to know if in your judgment if that was sufficient to fasten all those braces in their place?

A. I consider it was, with the block and the yoke.

Q. In the absence of the yoke, would it be sufficient?

A. I think not.

Q. In the absence of the lugs, in the place of blocks, would the yoke be sufficient to hold the braces in their place?

A. I think it would.

Q. In the inspection which you made of the bridge at that time and every time afterward did you notice, that those braces had been clipped off at the ends, when the change was made?

A. Cutting the corners off?

Q. Yes.

A. Cutting the corners off. Yes.

Q. Did that tend to weaken the braces?

A. I think not, sir.

Q. Would it not tend to throw the line of compression away from the centre?

A. I don't consider it would effect it materially.

Q. If the centre line of compression is thrown out of centre of the strut, would it not weaken it very much?

A. Not without it was cut to some great extent.

Q. Suppose it was only one-half an inch?

A. It wouldn't effect it materially.

Q. You think then, that the strut eleven feet long, the line of compression being one-half inch out of the line of the centre iron, would make no difference in its strength as a strut?

A. No, sir; I don't think it would effect it materially.

Q. Did you notice at the time whether the sway rods connected the brace blocks, each brace block at the end of each panel, crossing each other?

A. My impression is now, it was at every other panel.

Q. Would it have been better if they had been at every panel?

A. It would have been better, sir.

Q. Can you state to the committee, how near to each other the struts are from one lower chord to the other chord?

A. I don't recollect positively; but I think they were in every other chord.

Q. Twenty-two feet?

A. Every other panel, I think, sir.

Q. The tension rods, how were they connected, between the lower chords, at what point on the lower chords were the tension rods connected running from one lower chord to the other. How large was the panel, in the lower plan of the bridge?

A. The strut running from chord to chord?

Q. I am speaking of ties drawing against the strut. How far apart they were?

A. They run every other panel.

Q. They would be twenty-two feet apart?

A. That is my impression about it.

Q. I will ask you, if you can state, whether they are attached at the odd panel, differing from those, where the strut is, so that those chords cross each other?

A. I don't know.

Q. If they did that, wouldn't that destroy the efficiency of the strut, and the tie bar?

A. They wouldn't be as serviceable.

Q. Would they be of any practical value at all?

A. Yes, I think they would.

Q. What would be the effect of drawing up these chords, we are speaking of now, on the lower chords of the bridge?

A. I don't think it would draw them out of line.

Q. Have you at any time made any calculation of the weight of the bridge and the strength of the metal in it?

A. I have not, sir.

Q. Can you state to the committee, whether the original plan which you speak of, has ever been sent before the coroner's jury, with notations of the size of those beams, or braces or the brace blocks?

A. I don't recollect, sir.

Q. Can you tell me what is the size of the braces, or main braces.

A. They are six inches, that is my recollection, and about four-inch flanges.

Q. Were any of them seven inches?

A. I don't recollect that they were, sir.

Q. Did you ever understand, that they were to have been seven inches?

A. No, sir.

Q. Can you gives us the thickness of the flanges, and the width?

A. I can't, sir.

Q. If there should be marked upon the original plan that the brace-blocks, lugs, were six inches apart, leaving a space of six inches between them, what would that indicate?

A. That the braces were laid flatways.

Q. Suppose there was a lug, also, below where the brace was fit in, further down the angle of the brace-block—I speak of the lug on the brace-block on each side, six inches, now I speak of one lower down, nearer the edge of the brace-block.

A. I think there was, sir.

Q. You say that it was marked in that shape, six inches square, that it would indicate that the braces were to go in flatwise?

A. Yes.

Q. When you went with Mr. Stone, I will ask you if the brace-blocks didn't indicate that thing.

A. I think it did.

Q. Were the braces put in that way by the mistake of Mr. Roger or mistake of the original plan?

A. I don't know.

Q. I will ask you, as an engineer, whether these braces ought not to have been fastened together, so they would all have acted together as one beam?

A. I don't know: I have no experience in building that kind of bridges.

Q. Without experience in that particular kind of a bridge, what would you say from your knowledge on the subject of braces?

A. I should say it would be better to have them fastened together.

Q. If they were not so fastened, then wouldn't that be one defect in the plan of the bridge? Would it be a defect in the plan of the bridge?

A. I don't think it would be one that would produce any material disarrangement.

Q. Your opinion, then, would be that it would not be material whether this brace was composed of one piece of iron or a half dozen, there being the same surface for pressure?

A. If proportioned right I think it would answer the purpose, and enough of them.

Q. I am speaking of the same quantity and the shape.

A. I think it would be better to fasten together.

Q. I understood that a moment ago, and I understood you also to state that it would make no material difference.

A. I don't think it would.

Q. Would it affect materially the strength, braces of the same quantity of iron and same surface for pressure, whether it was divided into a half dozen pieces or whether but one?

A. It might if there was a surplus of material.

Q. I mean the same quantity of material in a brace.

A. The same amount of material would be better.

Q. Would it make material difference whether it was one beam or six beams, it being the same quantity for the brace?

A. If they were held by the clamp, not if there wasn't any clamp to bind them, if they were not locked.

Q. Suppose they are locked firmly, that would leave your braces eleven feet, wouldn't it?

A. Yes, sir.

Q. Wouldn't it be materially weaker?

A. It would be some.

Q. Have you ever known another bridge to be built of wrought-iron on this plan?

A. No, sir.

Q. State to the committee whether this bridge was an experiment or not.

A. I should think it was, rather, so far as I was concerned.

Q. I will ask you whether the upper chords in each truss of this bridge was not the same size from end to end?

A. I think not, sir.

Q. If there is any difference, will you be kind enough to state it?

A. My recollection now is that they run from five-eighths to an inch or an inch and one-eighth; I won't be positive of it; that is my recollection, sir, now.

Q. Do you know whether the ties, or panel-ties, are the same size throughout the bridge, or whether they vary?

A. I couldn't tell you, sir.

Q. Isn't that what you have in your mind, when you think that there is a difference between the end and the centre of the bridge? Isn't it ties that you are thinking of rather than the upper chord?

A. No, sir; the upper chord.

Q. State what the difference was in the width of the chords.

A. From the end of the panel, my recollection of it now is, to the masonry not as wide, with that exception it was the same width thoughout, sir.

Q. In speaking of the thickness of the material for the upper chord, will you give us some idea how it progressed from thin to thick?

A. I couldn't tell you, sir. In the erection of the bridge I had nothing to do with it, and have never made any thorough examination of it myself; it is being done now.

Q. Who is doing it?

A. Mr. J. C. Williams and Mayor Hepburn are making the drawings; they are making up the plans—planning the parts as they are in the bridge.

Q. If it should turn out, in this bridge, that the upper chord was the same size throughout the bridge, would that be an error in judgment in its completion?

A. I think it would, sir.

Q. Have you seen a statement from any engineer, who has been examining the wreck, showing that the panels on either side of the centre of the bridge were too weak, by an actual measurement of the metal?

A. No, sir, I have not read the testimony in the case, and have not seen that statement.

Q. Did you ever see or examine the strain sheets of this bridge?

A. No, sir. There is one being made now, sir.

Q. How do you get the idea, and from what source, that the upper chord is thicker as you approach the center of the bridge?

A. One of the bridge men told me that, and am now making an examination to see how it is.

Q. You didn't speak of it from your own observation?

A. I haven't taken measurement of it myself.

Question repeated.

A. I have not yet, sir.

Q. Never, at any time, on that point?

A. No, sir.

Q. Did you ever, at any time, make an examination with a view to determine, yourself, the exact strength of the bridge?

A. Nothing more than being in it and upon it, and see the action of the train upon it.

Q. Never made any mathematical calculation or measurement?

A. Nothing more than the bottom chord.

Q. What was the size of the bottom chord?

A. It is double bars—five double bars of five inches in width by an inch and three-eighths or an inch and a half.

Q. What, in your judgment, was the cause of this accident?

A. I don't know, sir. It looks very much, sir, that something came off the track; that a car couldn't run off the track—that is only theory—without some tampering with the bridge; that something of that kind—in fact, I don't know; I had better answer the question "I don't know."

Q. I ask for your judgment.

A. I couldn't fix any thing upon it that would do; I might theorize upon it. I say I don't know.

Q. Have you any opinion upon that subject?

A. No, sir.

Q. State whether there was guide rails across the bridge.

A. Yes, on both sides, and extending a short distance both ways.

Q. Would it not prevent any car or locomotive from jumping the track?

A. I expect it would, sir, unless there had been some tampering between the rails.

Q. What was the strength of the cross-ties?

A. I believe three by five.

Q. How close together?

A. I think about two inches or an inch and a half.

Q. Broad?

A. Yes.

Q. State whether a locomotive and train of cars couldn't run across that, on that planking, without breaking.

A. It could, if it was running parallel with the rail or stringers.

Q. If it kept near the guard rail it could run from end to end?

A. Yes.

Q. What was there below this flooring upon which it rested?

A. Stringers.

Q. What was the size of those?

A. I think they were six by fourteen.

Q. What did they rest upon?

A. On the iron floor beams.

Q. How many iron floor beams were there?

A. There was three panels—forty-two or forty-three in the whole length of the bridge, I believe, sir.

Q. State whether there was any thing placed on the floor on the top chord to distribute the weight—in other words, to strengthen the chords in the panel.

A. Putting the floor beams on the upper chord.

Q. Isn't that an unusual way?

A. I don't know; it is done, sir.

Q. Ought there not to be something else there to assist in carrying the weight to the end of the panel?

A. I don't see why it should be; it don't occur to me now.

Q. I will ask you whether this chord—whether its particular office isn't simply to resist the compression? If, then, in addition to that force of compression, it is obliged to carry the whole load of a train passing over it, doesn't that double the strain upon it? In addition to the compressive strain, isn't there this lateral strain upon each panel?

A. With additional weight upon it?

Q. Additional strain?

A. It makes an additional strain when the weight comes upon it, if there is enough comes upon it.

Q. I know. Isn't there a direct strain upon the chord, the weight of the train passing over it in the way in which this was fixed, throwing the weight on the panels instead of throwing it at the end of the panel—instead of throwing it on the brass blocks and communicate it to the chord there?

A. The arrangement, I believe, first. The angle block was very near it; I will not be sure; some where about eighteen inches. Then the stringer, sixteen by fourteen, would carry it from panel to panel. It would be a very slight spring back. Three pieces, six by fourteen, would carry without much deflection.

Q. Well, three of those stringers, six by fourteen, would carry a locomotive that would weigh forty tons, would it?

A. It is entirely sufficient, sir.

Q. If there was any weakness in the upper chord, I will ask whether it wouldn't add to its weakness in that place—that is, the floor beams directly on the chord, without any thing else to distribute the weight to the end of the panel, except the wooden chord that rests on the floor beams?

A. Yes, it would, if it had a weakness.

Q. Can you state whether it is usual to put these floor-beams directly on the upper chord, or whether it is usual to put something else there, to strengthen the upper chord at that particular place?

A. I think it is generally put upon the end.

Q. Direct?

A. Yes.

Q. Was this bridge intended for a double track bridge?

A. It was built for a double track bridge.

Q. State to the committee whether, with a double track upon it, one-half of the trains wouldn't rest directly over the chord, or perhaps project out over it on one side.

A. Allowing a car to be ten feet, which I believe they are, it would be five feet from the centre of the rail to the outside of the car; that would be two feet and one-half car outside of the rails; then the chord is two feet nine inches entire width; half of that would be a foot and four and a half inches; that would give the projection beyond the floor.

Q. Wouldn't it be more than that? Wouldn't the outside rail extend directly over the chord on this bridge?

A. Yes.

Q. The centre chord?

A. I think it is the centre chord.

Q. What is the width of the track?

A. It is about five feet from outward to outward rail.

Q. Then it would extend two and a half feet beyond?

A. If the car was ten feet, the car would be two and a half feet outside of the rail.

Q. It would be outside of the centre chord, then, two and a half feet?

A. The car—yes, allowing it to be ten feet.

Q. Would a bridge of this kind be stronger if it had been wider and the chords further apart?

A. I don't know why it should, sir, if the materials were prepared right.

Q. State whether the bridge would have to be twice as strong, or more than that, if used for a double track, than if it was used for a single track.

A. Yes, sir.

Q. Have you been up to the wreck since it occurred?

A. Yes, sir.

Q. Have you examined any of the brace blocks there?

A. I have, sir.

Q. Did you notice, from the paint marks upon it, that these braces had slipped out of position?

A. I noticed that some of them had at right angles from the blocks.

Q. How far had any of them been removed?

A. I didn't measure it, sir.

Q. Some of them as much as two or three inches?

A. I think not; no more than one-half of that.

Q. Did you notice any of these brace blocks broken in two?

A. No.

Q. I will ask you whether you noticed any of these sway rods there?

A. I didn't; I would like to make a statement.

Q. Certainly.

A. When this accident occurred I had to put up a temporary bridge; therefore it took my time to get materials and men, and didn't have time to make an examination of the materials as I would like to have done, and it is almost impossible to do it satisfactorily until our trestle work was done and a diagram made of it, which is now being done; and I wish to state, too, I don't think the gentlemen that are making the figures upon that can agree until that matter is settled. As to the firm position, and at least the materials in the bridge, I have not had time, sir, and didn't make an examination there, as I would like to have made.

Q. I was going to call your attention to this subject, whether you had noticed any of those sway rods—say one and one-fourth inch sway rods—that had been cut down to five-eighths.

A. No, sir.

Q. In the cutting of the threads?

A. No, sir; I have not made any examination.

Q. Did you notice any of the beams of the upper chord?

A. No, sir.

Q. What would be the effect on a bridge such as this was, and a train running on the south side of it, across the side of it, and suppose there was a gale blowing from the north at the time, and if one or more of these sway rods were to break?

A. The result would be bad.

Q. How would you expect the bridge to act? What position would it fall? How would it behave?

A. I hardly know; I don't know what effect the flooring would have on the train in the going down of the bridge; it is difficult for me to form any opinion. The floor runs across the bridge, and spiked to all the stringers; anything striking that floor, if it was on the south chord, the floor would be so stiff that it would throw it off—throw the cars or train in one direction, and the bridge would go the other; whatever would strike that floor, and together with the T rails, with the chord on one side to give way where the train was, I should expect to see the floor going in one direction and the cars in the other, on account of the floor; that is what I should expect.

Q. What would be the effect on a bridge like that with a train running on it at the rate of ten or twelve miles an hour, and in running on it, would apply the air-brakes for the purpose of stopping the train?

A. I don't know how much it would affect it. If the brakes were applied to a train so as to slacken up the train gradually, and if it would come together with a compression, it might raise a wheel of the car from the track.

Q. What would be the effect on the bridge itself? State whether it would be a material matter, in your judgment.

A. I don't think it would be a material matter.

Q. What direction would the force be applied to the bridge in that case?

A. Sudden checking might produce a vibration of the bridge.

Q. Suppose, at the other end of the train, you applied steam to the air-brakes, and applied steam, for forward motion, on the other?

A. I don't think it would affect the bridge materially.

Q. Where would this strain come? Where would the force expend itself—that is, the two forces—where would they expend themselves?

A. The one pulling back and the other pulling forward, breaking a train, I don't think it would affect the bridge.

Q. Wouldn't it compress the bridge—the two ends—drawing it together?

A. I don't think it would materially. It might have some force, but not materially.

Q. You think it wouldn't materially affect a bridge of this kind?

A. I think so, sir.

Q. I will ask you whether it is part of your duty, as engineer, to look after the general safety of the rolling stock?

A. No, sir; I have nothing to do with it.

Q. I will ask you, why were not these cars supplied with some sort of stove that wouldn't burn up in case of accident?

A. I don't know, sir. I have nothing to do with the rolling stock of the road.

Q. Do you know of any such stoves?

A. I have heard, sir, with water underneath; for instance, if it was capsized, the water would put it out.

Q. What stove was it?

A. This was the Winslow stove, I think, sir.

Q. What was the probable cost of this iron structure?

A. I really don't know, sir.

Q. Can you tell me what it was intended to support per lineal foot, dead weight, and, also, live weight?

A. I can't tell you, sir.

Q. Can you tell us how much more expensive it would have been to build a stone structure than an iron one?

A. There was estimates made, but I don't recollect now.

Q. Can you give us some idea, for our own direction, on that point?

A. I would like to give an idea: but that might mislead, and sometimes makes trouble, because there's a difference in opinion. I don't know what the bridge cost. To begin with, I can give you my opinion—$25,000 difference.

Q. By Mr. Burns: Suppose it should turn out that the sway rods were an inch and a quarter in diameter, and the thread at the bottom was five-eighths of an inch—cut down to that—would you call that good workmanship in that bridge, taking every thing into consideration?

A. I don't really understand it.

Q. Suppose it should turn out that the diameter of the sway rods at the bottom thread was five-eighths of an inch, while the balance of the rod run through at an inch and a quarter, would you call it good workmanship?

A. No, sir.

Q. By Mr. Stone: Did you yourself, as engineer of the road, ever make a thorough inspection of that bridge?

A. So far as looking at it for the safety of the trains.

Q. Did you consider that you had made a thorough inspection? That is the question.

A. To make an analysis of the bridge, I didn't.

Q. I mean, by making a thorough inspection of the road, such an one as would satisfy you in your own mind that that bridge was perfectly safe.

A. Yes; that it was perfecty safe.

Q. I understand you that you made such an inspection.

A. Yes.

Q. How long since did you make such an examination?

A. I don't know. It has been some time. I have been on the bridge often and made an examination.

Q. You say you don't know how long it is?

A. No, sir.

Q. About the length of time?

A. That, properly, belongs to the bridge inspector.

Q. By Mr. Converse: I will ask you one question more: Did the company, or any of its officers, give any orders not to throw water on that wreck?

A. Not to my knowlede, sir.

Q. What preparations did the company make for protection in case of fire there?

A. At the bridge?

Q. Yes.

A. There were two barrels, sunk into the ground, at either end of the bridge, with brine; they were there.

Q. I will ask you whether there was a hydrant connected with the water-power there near the bridge?

A. It was not a regular hydrant. There was a pipe, so as to attach a hose.

Q. Did the company ever provide a hose?

A. There has never been a hose put there.

Q. Why not?

A. It was put there more for having a fountain, or for any purpose that we might want to use the water-works.

Q. By Mr. Brunner. Is there a regular watch at that bridge?

A. There was not, but there is now.

Q. By Mr. Wiltsee. No preparation for putting out a fire?

A. There is now.

Q. By Mr. Burns. There is a pump-house at the bottom of the hill?

A. Yes.

Q. That is the engine?

A. Yes.

Q. For the purpose of throwing water out of the creek up to your reservoir on the hill?

A. Yes, sir.

Q. What is the height of that reservoir above the creek?

A. It is about 105 feet.

Q. You have an engine-house with the capacity of throwing water up from the creek up into that reservoir?

A. Yes. We only commenced doing it, though.

Q. The engine-house was there at the time of the break?

A. Yes.

Q. State whether you had an apparatus, or way of attaching a hose at the engine-house?

A. There was connection with a pipe.

Q. At the engine-house?

A. Yes.

Q. Did you have a hose at the engine-house on that occasion?

A. No, sir.

Q. Never had?

A. No, sir. That was made there thinking, perhaps, we might want that water for some purpose, and the men put in the water-works thinking we might want a fountain there at some time; but since this destruction there has been a hose ordered?

Q. I wish you would explain to the committee what, if any, facility you had there under your control, or the company's, by which you could put water on that fire as the cars were burning.

A. We hadn't any.

Q. Nothing more than buckets?

A. No, sir.

Q. Then I understand you to say that outside of the assistance that you might have had from the village, the company had no facility for throwing water through a hose or otherwise except by buckets on that fire?

A. No, sir.

Q. It is true of your own personal knowledge?

A. I don't know any thing to the contrary, sir.

Q. I mean at that day—at that point—there was no facility for throwing water through a hose?

A. We had none there.

Q. State to the committee whether the village hose, or the hose of the village fire department, fitted the fire plug at the abutment of your bridge, if you know.

A. I don't know—I couldn't tell you.

Q. State to the committee, then, if you know, what hose and what fire-plug that rumor refers to about the employés of the company not being able to fit the hose on to the plug?

A. The person at the pump-house told me that he tried it and it wouldn't fit. It didn't go on easy, and he supposed it wouldn't fit at all. He afterward found out, by wrenching hard, it could be got on.

Q. What wouldn't go on?

A. The cupping.

Q. The hose cupping?

A. That is what I understood.

Q. What hose cupping?

A. The village. He told me had tried it.

Q. He is your employer?

A. Yes.

Q. At the pump-house?

A. Yes.

Q. When was it? Did he tell you that he had tried to put it on during the fire?

A. No, sir. He didn't state any time?

Q. When did you understand him that he had been making that experiment?

A. He didn't mention any time—I couldn't really say.

Q. State whether, from any source that you know, that any experiment of that kind was made with the village hose on the fire-plug during the time of the fire?

A. I don't, sir.

Q. What is the name of the gentleman that told you?

A. James Manning.

Q. Is he the manager of the pump-house?

A. He runs the pump.

Q. By Mr. Converse. How were those floor beams attached to the upper chord, or fastened to it?

A. There was lugs riveted on the floor beams, resting on the inside of the chord, and then the stirrups.

Q. What is the size of the stirrup?

A. I couldn't tell you—five inches or eight. I couldn't tell you.

Q. Now, right in that connection, what would be the effect of applying air brakes on that bridge, upon these floor beams, as to whether it wouldn't shove them right along?

A. I think not, sir.

Q. What would there be to prevent that, except this little stirrup, if there was one?

A. The railing having fish-bolts to it, the rail couldn't move. I don't see how it could transfer this motion to the beam, sir.

Q. Is it unusual for these rails to break in the case of an accident of any kind?

A. Well, we have sometimes a broken rail, sir.

Q. Why couldn't the whole bridge be shoved right along—break off clear—say down this chord; it isn't very far, of course it couldn't go but a few feet before it would strike the panel. Why couldn't the whole of it be shoved right along?

A. You would have to take the rail with it. I don't see how you could take the rails, spikes, and fish-plates on it.

Q. Suppose you move the whole rail?

A. I don't see how that could be done. The fish-plate on the rail, and the rail fastened, sloped, and spiked.

Q. How were those lugs put on the floor?

A. Riveted it on the beams.

Q. By Mr. Stone. Is it not the habit with engineers on the road to run under a full head of steam just as long as they can, in order to have time to check up when they stop at different stations?

A. So as to make a shorter time at the station.

Q. That being the fact, and this bridge being near the station, and running, as you say, as fast as they can, in order to make the check at the station, and that being done every day, and then go out under a full head of steam, would not that in time have an effect, or damage the strength of that bridge?

A. If the train was suddenly slacked, and the train coming together suddenly, it might raise the wheel off of the track.

Q. That thing kept up every day there, so close to the station, would it not in time have a material effect upon the bridge?

A. It would be a very long time that it would have any effect.

Q. By Mr. Brown. Would there be any necessity of the company's keeping a hose there at that engine-house, considering that to be an iron bridge? I understand it is only at wooden bridges.

A. We would have a hose there, probably, if there was no bridge there, for the purpose of wetting the ground and keeping the grass bright—we often do—and if there should be a fire about the building or coal-house, or about the vicinity, it could be used for fire purposes.

Q. It wouldn't be a necessity as far as the bridge was concerned?

A. No, sir; I don't think it would.

TESTIMONY OF ALBERT CONGDON.

Albert Congdon, being duly sworn, testified as follows:

Q. By Mr. Converse: What is your full name?

A. Albert Congdon.

Q. Where do you reside?

A. At Elyria, Ohio.

Q. State whether you were at any time in the employ of the Lake Shore Railroad Company.

A. I was in the employ of the Cleveland, Painsville and Ashtabula, finally the Lake Shore Railroad Company as you call it, for about sixteen years, perhaps.

Q. Just state between what period in answer to the same inquiry.

A. From April 1, 1855, I think, to April 1, 1871 or 1872. I declare I don't know which, 1871 or 1872.

Q. State whether you had any thing to do with the erection of the so called Ashtabula railroad bridge.

A. I had to do with the manufacturing. That is, fitting up the different parts of the bridge.

Q. In what capacity were you employed?

A. A master machanist.

Q. Who furnished the plan for the Ashtabula bridge, that you worked by?

A. The plans were handed to me by Mr. Tomlinson, I think a man by the name of Tomlinson drafted the plans.

Q. State whether you had any thing else to do in connection with the bridge, except the manufacturing of the parts of it, at the machine shops?

A. Well, I had. I ordered some portion of the materials. I made some little sketches for articles that we applied to the bridge to strengthen certain parts.

Q. Just state what parts—give us the items.

A. If I had the plan of the bridge, it would help me considerably I think I can give it so you can understand it; the plan of the bridge would help a good deal.

(At this point the plan of the bridge was sent for.)

Q. You can proceed now, so state what parts, as well as you can.

A. Well, the end braces, for instance, the braces in the end panel, I made a strap or stay, to stay those braces.

Q. By Mr. Haynes: I would like to know, at whose instance that was done, under whose direction.

A. Well, it was done after I had pointed out to Mr. Stone, and made my suggestion to him; he told me to go on and do as I had suggested. Mr. Stone was the President of the road.

Q. By Mr. Converse: What provision did you make to strengthen those braces?

A. I put a heavy strap of iron on the top braces, and passed the bolts down through; that, with a heavy strong strap under the bottom chord, connected the center bracing firmly with the bottom chords.

Q. State whether that was of wrought iron.

A. Yes, sir.

Q. By Mr. Haynes: Attached at each end?

A. No, sir.

Q. By Mr. Converse: Where did it attach to the lower chord from the upper brace block?

A. At the end of the bridge, where the first panel commences—that is, the braces from the top angle block. The first angle block in the bridge went back. There was an angle block on the bottom chords that the suspension bolts passed down through the upper angle blocks; and the upper angle blocks, large bolts, with large heavy nuts on them; those nuts were turned square, so that the bar of iron I had under the chord, you know, would back right up against those four nuts. For instance: the bolts might be, well, about 1½-inch bolts, as I can recollect; I haven't had any time to refresh my memory in reference to the bridge since it was erected, about eleven years now. The under bottom chord backed right up against these bolts' heads; then between the bars there was a space for bolts to come up, so that I put another strap right on the top chord, right over the strap that I had on the bottom side of the chord, and put two bolts through that—through the two straps, so as to hold the straps together, so it wouldn't spring in the center. If I had these bolts attached to the straps at the end, the tendency would have been to have sprung together these straps under the center, so I put a strap above the bars, so it kept perfectly stiff, you see. It made a short leverage on the strap.

Q. That was only on the lower chord?

A. Yes.

Q. Did you make any other changes outside of that?

A. I can give you a description. (Illustrates.) This strap went through here; then from this bottom strap, he had two rods attached to that, one on each side of the chord, close to the chord, to the bottom chord that passed the braces; then there was a hoop strap put across that these bolts run through, and there I screwed them down until they became solid, and put a nut on the end side, you see; and there were three bolts, two-inch bolts, I think, there, that passed through this top strap, you know, back of the main brace there, passing through between them, and were screwed in the angle block. The first angle block they had, and very light, held in the casting; and from my practical knowledge of such matters I was satisfied that in a very few days, by the passing of engines or trains over the bridge, these threads in the cast-iron would crumble right out, because they had only about an inch hold, about the number of six threads to the inch perhaps, and I thought it was very inefficient and very dangerous, and that was the reason of my making this additional security. These bolts passed through this strip you see into the casting—passed between these bars, with a good strong thimble, and then they were screwed. A nut was screwed on to the end. These three or four bolts, I forget which now, on the top of this strap there, held the thing stiff—very stiff.

Q. Was that thimble cast?

A. That thimble that went over the bolt merely acted as a stirrup, and the brace was only screwed up. I would n't screw the braces down in the centre.

Q. How many of them were put in the end braces?

A. What do you mean?

Q. These rods with the thimble running up and meeting the braces half way.

A. I am not positive; there were three or four of them.

Q. At each end of the panel?

A. Yes; three or four of them; and they were as large as two-inch bolts, you know, of good iron.

Q. What other changes did you make?

A. Well, I put in larger bolts where the braces cross each other in each panel. For instance, there were $\frac{5}{8}$ or $\frac{3}{4}$ bolts put in there originally, according to the plan, and I put in an inch in there. I think in the first place they were five inches to the rule. They clamped or clustered the bars together.

Q. You refer now to stirrups and rods that pass around the braces in the middle?

A. Yes.

Q. Did you make any other changes?

A. The braces were put in originally in the bridge so that the web was in a horizontal position. The braces were six inches deep this way (showing), and had a flange on each end, about three or four inches. They were put in flat-wise like (showing). I saw them pointed like that (showing). I suggested to Mr. Stone the matter. I told him if they were turned edge-wise like that (showing), they would support more than twice the weight. I proved that idea; and, in fact, he told me to go on, and do as I suggested.

Q. When did you make the suggestion to Mr. Stone to change the beams from "H" to "I" beams?

A. The "H" beam is this way (showing) and the "I" beam is this way (showing). It was after the bridge, that is, the trusses had been tested, and were found not to hold the camber in the bridge. I can't say the day.

Q. It was after the bridge, in fact, had been set up?

A. The trusses had been set up and screwed up, and rested on the trestle weight.

Q. And then you let it down upon its own weight, and it would n't hold its own weight?

A. Yes.

Q. Do you know whether Mr. Stone was sent for at that time to see the bridge?

A. I do n't know whether he was sent for or not.

Q. By Mr. Haynes: Did he come?

A. He saw the bridge in that condition. I was with him.

Q. By Mr. Converse: Do you remember whether Mr. Collins was there?

A. He was not to my recollection. I am positive he was not.

Q. I will ask you to state now whether the braces were changed so as to make "I" beams at your suggestion?

A. They were.

Q. What other changes were made at that time, if any?

A. At the time the braces were changed from horizontal to vertical, an additional number of braces were put in.

Q. How many additional?

A. Well, there were two additional braces put in—put at each end of the panel.

Q. How many were in the end panels before?

A. I think there were four.

Q. That made six?

A. Yes.

Q. How many were added to the second panel?

A. That I can't recollect.

Q. Were there any additional?

A. I can't say.

Q. If it should be found that there was five in the second panel, could you say from that that there had been an additional number put in?

A. Yes, I should say that there was; that is my impression.

Q. Were you there when the bridge was put up—set up in place?

A. It was through the braces; setting it up do you mean?

Q. Yes.

A. I visited it there, but only stayed a few minutes, and be off again. It wasn't every day or every week.

Q. I will ask you whether you superintended the casting of the brace blocks?

A. I didn't.

Q. Who made the patterns?

A. My pattern-maker.

Q. What is his name?

A. O. Hayward.

Q. State whether the lugs on the brace blocks were afterwards chipped off?

A. In changing the braces from horizontal to vertical, there was a portion of the lugs chipped off. I will explain why it was. On each side of the brace blocks or plane that set in the angle to the bridge, there was a strip from some two and a half inches wide, planed lengthwise. Mr. Tomlinson made the drawings or working drawings for the angle blocks. Well, for instance, I told Mr. Hayward to be very careful to make those patents exactly to the drawings, and before the castings were put into the sand to have Mr. Tomlinson's approval that they were correct, and he did so. I knew that Mr. Tomlinson approved of the blocks before they were moulded. After they were cast, instead of their being perfectly plain parallel, the blocks were sprung in cooling, as metal will, so that they were crowning—that is, on the bearing side.

Q. Well, that plane surface was not large enough for a set of braces?

A. That is all that I got planed, without planing the lugs off, so it gave me a guage to go by.

Q. What was the purpose or use that those lugs had?

A. I don't wish to be examined as an expert; I can give you my judgment in the matter.

Q. You are a master-mechanic, and therefore ought to know what those parts were for.

A. Well, it was after, although I didn't ask what they were for, but it was after, that it was intended to keep the braces in position.

Q. I will ask you, when it became necessary to change these braces from "H" to "I" braces, wasn't you obliged to chip those lugs?

A. A portion of them were chipped off. I didn't see that they were entirely chipped off. But as to being any benefit to the braces after they were turned from "H" to "I," I didn't think they were.

Q. Ought there not to have been some thing to hold those braces in place?

A. I will answer you according to my mechanical ability. I have thought it was necessary to keep the end braces in position.

Q. Have you manufactured other brace blocks besides those?

A. Yes, sir.

Q. You may state to the committee whether it is customary always to make some provision for holding the foot of the braces.

A. In all the angle blocks I have made and fitted for bridges, and have fitted a good many, I have always drilled in the holes in that position, for instance a five-eights, and put a jowell into the end of the timber in a proper position to go into that hole in the casting. That, in a wooden bridge, is merely for the convenience of raising; there is more surface to a wooden brace, a great deal, and very often they get out of position.

Q. Doesn't the jowell pin hold them in position?

A. It does. You may take a five-eighths pin and drive it into a pine stick, and it would take no great power to move it.

Q. Let me ask you, in your judgment if it wouldn't have been wise to have had some such provision made for these braces?

A. By my judgment it would have been well to have had those braces held firmly in position.

Q. Above and below?

A. More especially above.

Q. Do you know anything about an upper chord being too short at any time?

A. Yes, sir.

Q. State what you know about it?

A. Mr. Rogers, the man that was erecting the bridge; he notified me that he wanted to see me at Ashtabula, while he was erecting the bridge. I went to Ashtabula and met him, and he said that he couldn't get in the top chord, that it was too long, something over three inches. Well, I knew it wasn't too long. I made it accurately, according to the drawings, and every thing according to the drawings, both top and bottom chord, and there wasn't a possibility of its being too long. I knew it. Well, he went on to explain. He said, "Now you draw a base line,"—the bridge was one hundred and fifty feet long, and it was intended to be about four inches camber—"you draw a base line," he says, "then you go to the center and erect a perpendicular of four inches, then," he says, "you draw a line from that perpendicular to the base line, seventy-five feet, and then measure the perpendicular from the parallel line to the center, and then measure the distance from the angular line to the perpendicular—that is four inches raise; and there is no doubt one-sixth of an inch difference between the two lines—hardly that." I saw that he didn't understand the principle of structure. I listened to him, and was satisfied that he didn't understand, and I told him. Says I, "Mr. Rogers, you don't apparently understand the principle of structure; there is no straight line about this; it's segment circle," using terms to explain it to him.

Q. Just tell us the result.

A. Well, he reported to Mr. Stone. Mr. Stone sent for me to come to his office. I went there. He told me that Mr. Rogers had reported to him that the top chord was too long, and told me to shorten it.

Q. By Mr. Burns: That is, Mr. Stone?

A. Yes. I did so; I shortened it.

Q. By Mr. Converse: Well, how much?

A. I think, three inches and a quarter. Then they put the top chord in, screwed up the bolts, and when taking the blocks down from under the chords the bridge settled right down; it came down until it was about two and one-half inches concave; and then they didn't take out any more; they stopped. And then Mr. Stone became acquainted with the state of things, and he asked me to go down to Ashtabula with him; we went down and looked at the thing, and then he said that the top chord was too short, and it must be lengthened again to its original length. I lengthened it.

Q. How did you lengthen it?

A. I put in wrought iron plates between the ends, and bars under the lugs. For instance, the top angle blocks for the purpose of bars, butting against the lug there, I put in plate.

Q. Are those plates called shins?

A. Some call them so.

Q. How thick were they?

A. Some of the plates were one-fourth of an inch, and some, I think, one-eighth; that is according to the best of my recollection.

Q. What was the length of the bar in the upper chord?

A. It was a little short of twenty-two feet; I can't tell you exactly.

Q. That would make seven spaces, wouldn't it?

A. The panels were what was called eleven feet panel on the bottom chord, and then the crown of the bridge made a little difference; and then one bar went over two panels, and then there were three lugs, which would reduce the thickness of the lug.

Q. Didn't you put in two of those shins, one on each side of the lug, on the brace block?

A. I did.

Q. If they were one-fourth of an inch, they would make a half-inch stretch?

A. If they were that.

Q. There would be six of them?

A. I suppose you have figured it.

Q. Yes.

A. I suppose so; if they were one-fourth of an inch, and if there were six lugs on the brace block, that would make three inches for the lengthening of the upper chord. You don't count the end of the angle block, where the braces stop, do you?

Q. No, sir.

A. There was a shin put in; that would make the seven.

Q. By Mr. Burns: That would be three-fourths of an inch?

A. Yes.

Q. By Mr. Converse: And then you lengthened it three-fourths of an inch by shins?

A. Yes.

Q. State whether any other changes were made at that time.

A. At the time of lengthening it?

Q. Yes.

A. No, sir; not at that time.

Q. By Mr. Haynes: If those shins being put in there, would it strengthen it, or weaken the bridge?

A. Neither.

Q. By Mr. Burns: Did that resting of the counter differ from what it was originally intended?

A. When those were put in, and the bolts were screwed up solid, then the wedges were reduced under the chords; this is before they were turned up edgewise; the bridge settled right down again to its original convex shape, and when it got down two inches and a half, or near that, we didn't take out any more blocks.

Q. By Mr. Converse: That was the second time it had settled?

A. Yes.

Q. State what occurred then?

A. Well, then, Mr. Stone, two weeks, I think, after that, he called me to his office; he turned and spoke to me and says, "Mr. Congdon, that bridge doesn't quite suit me yet;" and then he stopped; he didn't say anything further; and then I spoke; I says:

"If you will allow me, I will express my opinion and give you my views in reference to the bridge;" or words to that effect. Well, he didn't object to it, so I went on. I told him, says I, "You will recollect when you were down to the bridge and having cause to examine it, when we stood in the center"—that was down in the bridge, on the plank to walk upon—"you perceived when we stood in the center of the bridge, the braces at the center panel stood about—that is, they wasn't straight—you couldn't perceive that they were bent; but you go to the next panel from the center and you discovered they were a little bent, and more and more, and increased until we got to the end of the panel."

Q. What did he say?

A. I kept right on; I says: "If those braces were turned up edgewise," says I, "they would be more than stiff again, and add no more weight to your bridge; you would have more than twice the carrying weight without adding any extra weight to the bridge;" and then I spoke to him about the fastening of the end panel, and gave my description how it could be fastened.

Q. By Mr. Burns: In each end panel?

A. Yes.

Q. By Mr. Converse: State whether you did at the same time, strengthen the last panel, the bottom chord of the last panel?

A. No, sir.

Q. What fastening did you make for this small strut, extending under the bridge?

A. I gave a description of that. I put a strap of iron right under the bottom chord, the second brace block, between the second and third brace blocks, clear up to the nuts in the second brace block, so that this strap backed right up solid against those nuts, and then I put a strap right on there on the top, right over the strap. I had under the bottom chord a bolt, the bottom strapped firmly to the top strap above the bottom chord. Under the bottom chord was forward an arm to it; it projected up on the angle of the bolt or short strut that held the brace in the first panel at the centre. This arm was connected by an inch and three-fourths rod that passed through a heavy strap on the top of the end brace, and held fast to that by two nuts.

Q. The point I was asking about, how did you fasten the end of the small strut to the bolt that you placed at the bottom of the lower chord in the second panel?

A. A thimble.

Q. How was that fastened to this strut?

A. It wasn't necessary. This was forwarded there, with an arm, and it was here it was connected.

Q. I want to know how that connection was made. Was that cast in one piece? Was the end of the brace extending through the length of the second panel on the lower chord, were they fastened at the second brace block?

A. At the second brace block they were fastened, that covered the strap that was underneath the bottom chord.

Q. I don't think you got my question. The question which I put was, I want to know how this short strut was fastened to the plate, if at all.

A. It wasn't fastened at all.

Q. How ought that plate, then, in the lower chord in the second panel, sustain the short strut?

A. It went right around it.

Q. Whether this short strut didn't go through the lower end and fasten at the nut at the bottom?

A. No, sir.

Q. Was there any other fastening to the end of this short strut except its connection with the casting?

A. At the casting only.

Q. How were the splices made in the upper chord?

A. There were no splices in the upper chord. They broke joint.

Q. Were there any of those bars in the upper chord that passed over the brace block?

A. One bar.

Q. Was there any thing to hold them to the brace block?

A. Nothing but their weight and this bolt, that had a washer under the head—the bolts that rested on top of the bars in the top chord.

Q. What prevented the braces shoving the upper brace block along the upper chord?

A. They broke joint. I can show you here.

Q. I have it in my mind.

A. Here is one bar, that laid close up to that lug on that brace block there. We passed over that brace block, you see, up against the lug, next to the one outside.

Q. Was there any thing except the two lugs to keep the brace blocks from slipping along the upper chord?

A. There was nothing but the lugs.

Q. Were there more than two lugs on the brace blocks?

A. I think not.

Q. Was there any thing to keep the brace blocks from slipping along the upper chord?

A. No, sir; except the two lugs.

Q. I want to ask you right here this question: Ought there not to have been some provision made so that each one of the bars in the upper chord might have been held at each brace block, instead of breaking joint? Might there not have been some device invented to have held each bar at tne brace block?

A. Each bar was held by the lugs.

Q. There were only two bars held and three passed over?

A. Each bar was held by the lugs.

Q. Wasn't they held eleven feet apart?

A. Yes, sir.

Q. I will ask you, between the bottom chords, the bridge was manufactured and put up as represented on this plat, so that the ties passed over the end of the struts between the bottom chords, crossing to the tie on the opposite side, or whether the ties were put in at alternate blocks, crossing the strut in the centre?

A. They were not put in according to the plan, but they were put in so that they crossed the strut.

Q. I will ask you if that wasn't an element of weakness in that bridge, in your judgment?

A. It might have made a trifle difference.

Q. Did you ever ride over that bridge?

A. Yes, sir.

Q. How did it behave under a running train?

A. Well, I haven't observed, for a number of years. For perhaps three or four years after the bridge was erected I rode over it frequently, and it behaved very well. I can't say that I have rode over the bridge to observe how it behaved since it has been used much with a double track on it.

Q. When was the double track put on?

A. That I can't say to a certainty.

Q. Was that bridge intended for a single or double track bridge?

A. I never asked what it was intended for; but it was of that width that it may have a double track on it some day.

Q. Did you ever state to any one that it was intended for a single track?

A. No, sir. I have stated it was very serviceable for a single track.

Q. Did you understand, when it was completed, from Mr. Stone or any of your superiors, that it was intended for a single track?

A. No, sir; I have never heard it ever suggested to me that it was intended for a double track.

Q. By Mr. Haynes. I want to know whether both tracks were put on at the same time?

A. One.

Q. How long before the other?

A. It seems to me it must have been some four or five years before the other track was put on to be used as a main track. There was a side-track put on it, with the switch at the east end of the bridge, which, of course, used the north chord but a little.

Q. The south track was put up first?

A. As a main track it was put up first, that is to say, that the side-track, while a side-track, was on the north side of the track; the side-track got a good deal used more than the north track did; this south track was actually used more than the north track.

Q. What I want to know is whether one track was put up sometime before the other?

A. Yes, sir, it was.

Q. How was the other attached to that? Was it the same as if both had been built at once?

A. It was moved over one track; when they were building up the end of the bridge they put the rail on the south side of the bridge, outside on the truss from the main track that run through the centre of the bridge, and used one track—one rail, you know, of the main track; and this extra rail they put on was out on the edge of the bridge, for the purpose of dumping dirt and make a fill.

Q. By Mr. Converse. I will ask you if you know E. C. Gresnold, of Elyria?

A. I think I know a man by that initial.

Q. A book-store man?

A. Yes.

Q. Do you know a man by the name of H. E. Fisher, grocer?

A. Yes, sir.

Q. I will ask you if you stated to either of them if you always regarded this bridge as a failure?

A. No, sir.

Q. I will ask you to state now whether you didn't regard it as a failure?

A. Well, I suppose you want my opinion?

Q. Yes.

A. My opinion of the bridge—of course you understand that I don't pretend to be an expert, but I have some judgment about matters—perhaps if the bridge had been well attended to, which there is ample evidence that it was not, and that I should have recommended, when they used a double track, to put in another truss.

Q. By Mr. Burns. A third truss?

A. Another truss, yes, sir.

Q. By Mr. Haynes. From your experience in building bridges, engineering, and your practice and knowledge as a railroad man, do you believe that that bridge, in your opinion, was safe, for the amount of business on that road?

A. All things have an end, perhaps?

Q. Yes.

A. I am satisfied in my own mind, that if the bridge had been well attended to, as soon as there was any thing wrong and showing a disposition to be working out of place, and fastened, as it might been fastened easily, the bridge would have been standing now. But to use it as a double bridge, and the heavy machinery which they have added to the road since the bridge was completed, I don't think it was safe.

Q. Did you visit the bridge of late years?

A. I haven't examined the bridge since two years after it was completed; and then it had been used as a single main track bridge. I went down there and examined it as thorough as I could, with the facilities I had for climbing around it, and examined the chord more particularly, to see if there was any sign of its giving at all where the lugs were welded on to the bars; you see, that was the only point that I would be afraid that they would ever crack or come out, that held the angle-block; I examined it thoroughly, and a day or two afterwards I told Mr. Stone, at his office, I told him I had examined the bridge and it looked very well; I didn't discover any thing but one brace, and that was but a trifle out, I could just jar it; it was probably loose enough—oh! you couldn't slip a bank-bill between the two wedges; it was an outside brace, and in about the third panel from the east end, as near as I can recollect. As I knew Mr. Rogers had the superintending of the erecting of the bridge, I told him of it. My idea was that he would go perhaps and turn up that outside nut a little—it didn't require but a sixteenth turn, probably.

Q. Did you notice it or examine it since the disaster?

A. Yes, yesterday.

Q. How far were the braces out of position?

A. They were from nothing to one and a half inches, what I saw out of position.

Q. How did you discover it?

A. It has been painted since they were out of position, and there was the paint covering the original set of braces; so it was after they had been painted, the braces were out of position, some of them more than one and a half inches.

Q. By Mr. Haynes. That would have a tendency to weaken the bridge?

A. Very, very little.

Q. That bridge was built some years ago; did it contain matters of structure that is now used in building bridges, or was it a pioneer?

A. It was an iron bridge on the Howe plan.

Q. Has there been any improvement on it since?

A. In bridge building?

Q. Yes.

A. I suppose there has been a good many since I suppose Howe had his bridge.

Q. Do you consider that one the best structures designed for the purpose for what it was used?

A. Yes.

Q. The design of this bridge as an iron bridge, do you believe it was sufficient?

A. No, sir.

Q. Did you notice any crystallization or less tenacity of the iron?

A. In all the iron I examined, so far as the things that were bent and broken, it all shows to be a first quality of iron; that is as far as you can discover by the eye.

Q. By Mr. Converse: The packing between the stirrups and the rods holding the braces in the centre. What was the packing?

A. It was. That was a piece cast. You mean where the braces cross?

Q. Yes.

A. That is casting put in there for packing to hold the braces. For instance, in the centre, in the right position. When we turn them over we had to fill up the space with packing.

Q. In these lugs that were put in weren't they originally designed for the brace as horizontal braces?

A. No, sir.

Q. And when you turned them over as I braces, didn't the flanges of the braces strike simply the edge of the brace?

A. I think not. I think the packing that was there when the bridge fell, was packing made especially for the change—why they were changed to I braces.

Q. By Mr. Stone: I understood you to say that you believed that if carefully watched, that it was a good bridge, and it required care taken of it?

A. I said that the bridge had evidence of not having care—not being watched.

Q. Whose duty was it to give it that attention and care that you have reference to, that it didn't have?

A. As far as I know it was in the Chief Engineer's department.

Q. You spoke about some of these braces being moved, and it had been painted since. Do you know how long since it was painted?

A. No, sir; I don't.

Q. By Mr. Brunner: Are you connected now with the company?

A. No, sir; I am not railroading at all.

Q. By Mr. Converse: Do you know any thing about this disagreement, if there was any, between Mr. Stone and Mr. Collins—what the cause of it was?

A. Well, I don't wish to say that I could state positively.

Q. State all that you know about it.

A. My understanding was, and I give it in this way: When there was a mistake discovered, which was of some considerable importance, Mr. Tomlinson asked me if I thought it was best to let Mr. Stone know of it? I told him of course, I would let him know of it. I supposed that he did. Perhaps it was the next day or two that he came to me and said that Mr. Stone had resorted to turn the bridge all over to me, and I was to go on and finish up the bridge; and then a few days after Mr. Stone told me to go on and finish up the bridge, and I suppose it was on account of the mistake that he left.

Q. I mean Mr. Collins instead of Mr. Tomlinson. What do you know of any difference between Mr. Stone and Mr. Collins in relation to this bridge, and what was the cause of it?

A. I don't know of any thing. I didn't know that there was any difficulty at all, or difference between Mr. Stone and Mr. Collins in regard to this bridge.

Q. By Mr. Burns: Between Mr. Stone and Mr. Rogers?

A. Mr. Stone and Mr. Rogers—well, I don't know that I ever knew of any difficulty between these two men.

Q. By Mr. Converse: Do you know whether Mr. Collins regarded the bridge as a safe bridge or otherwise?

A. I have no recollection that he ever expressed an opinion to me about it.

Q. You have no knowledge on that subject?

A. Well, it don't occur to me now. Something might refresh my memory, but it don't occur to me now.

Q. By Mr. Haynes: What is your experience as an expert—as a mechanic? Do you consider an iron bridge as safe as a wooden one?

A. In regard to temperature, weather, etc.?

Q. Taking every thing together.

A. I will have to answer that in two ways. For instance, you can't burn it up, and a wooden bridge you can; that is one principle of it that would be safe; but as to the other, in an iron bridge there is more material that is affected by the cold weather than there is in a wooden bridge. In a wooden bridge there are the irons and suspension bolts that are subject to cold weather, just the same as it is in an iron bridge.

Q. Stone culverts or viaducts are safer?

A. If they are constructed in a proper manner.

Q. And constructed mechanically?

A. And good foundation, and good materials, in every respect, it is a safer structure. There is no doubt about that. If they are constructed in right proportion, you can probably make them safer than a wooden bridge or an iron bridge. Iron bridges can be made very safe.

Q. Has any iron bridge been used of sufficient length of time to demonstrate their utility, or is it all in theory?

A. Well, in this country we haven't used an iron bridge as long as they were in the old country. The first bridge that I remember of, must be thirty-five or forty years old, and I think I saw it six or seven years ago, and was over it. I guess they have got good engineers in that country.

Q. That is the old country?

A. Yes, England. They have good men in that country, experienced men, that understand their business.

Q. Most of our iron bridges, according to my recollection, have failed in this State?

A. There have been a few.

Reëxamination of Mr. Congdon.

Q. By Mr. Converse: I will ask you what this bolt is?

A. That was a shim to lengthen out the top chord.

Q. By Mr. Burns: None like that to go up back of it?

A. The other side of the lug, or else go between the ends of the bars. There is another bolt, about six inches square, which run between the ends of the bars—that is, right between the lugs. It was held so it couldn't come out by the bars.

Q. By Mr. Converse: You may look at the other piece and give your impression as to the packing that was in the stirrup and bars at the center brace.

A. I should judge that is one of the pieces to the flange; seems to have been screwed up against those lugs.

Q. I want to ask you whether the old packing wasn't used when the braces were changed from H braces to I braces?

A. I can't say as to that, but I think I made new packing for the change. This might have been a piece that they worked in somewhere.

Q. By Mr. Stone: The old packing?

A. Yes.

Q. By Mr. Converse: Look at the hole through the end of that, and see if it has not been enlarged so as to convey from a five-eighth inch bolt to convey an inch bolt.

A. [Examines it at the window.] I can't tell, unless it was cleaned out. It looks here as if it had chips off.

Q. Doesn't that indicate that it was rimmed out to convey a larger brace?

A. That was a break-down in the sand that held the metal, and they had to chip there. [Showing.]

Q. Isn't this a part of the packing that was used for the beams before they were changed from H to I beams?

A. It couldn't be. If inch packing, it wouldn't need such heavy packing, like that.

Q. That lug held it from swaying the other way when it was used as an H beam—the beam fitted right in that way? [Showing.]

A. Yes.

Q. Back to back?

A. Yes. Then in between here [showing] there would have been a thin space, you see.

Q. Would that have filled the whole space?

A. The back, you know, had to be put in one way, in order to get the bolts two inches along the packing. How could we use a four inch space for a six inch bar?

Q. Because the bar was turned around.

[Witness makes a sketch.]

A. This represents the four inch cross. Well, take and make a six inch cross—the bolts come right close in here. You couldn't use, you see, a four inch for a six inch bolt.

Q. As a matter of fact, I will ask you if those brackets are not to-day a fraction over six inches.

A. I can't tell you.

Q. If those brackets are six inches, what, then, would you have to say about the original packing having been used after the bridge was changed?

A. I would take rather more than six inches.

Q. Six and three quarters?

A. Yes.

Q. Did these braces, when they were finally used—was it the six inch way or the four inch way?

A. The six inch way when the bridge went down—that is, vertical; the web was up.

Q. Wouldn't that have left the brace six inches apart or six and three quarters?

A. [Witness takes piece of iron and demonstrates.] Well, for instance, here it is. The brace is six inches; you turn them up edgewise; there would be six inches and a little over. Of course, when these braces were changed, the center of this should have been right central with that, and kept the braces central. Well, now, of course, that brought the bars further apart, so we made the packing especially to fill it—the space—that space was produced by changing the brace in the other position, which made the space further apart.

Q. Now let me ask you, instead of changing the packing didn't you take the old packing and simply use these flanges to strip the flanges of the beams for packing?

A. I think not, sir.

Q. Do you know whether these marks in here were made by rubbing or vibration?

A. I think it was.

Q. Why should it be so light?

A. Oh, well, I think this measure here was made just the same thickness as the old pattern was; and then these lugs were put in, in addition, to fill the space. The main thing was probably just the same thing as the old pattern.

Q. Don't you see the space was not increased from outside to outside?

A. We don't seem to get our ideas about that.

Q. That is immaterial.

A. From this point to that point, do you mean [pointing on the iron]?

Q. I mean the other way; increase the section this way [showing], the distance wouldn't increase or diminish when you turn the brace over; you keep the same space exactly?

A. We had to thicken up the packing.

TESTIMONY OF A. L. ROGERS.

A. L. Rogers, being duly sworn, testified as follows:

Q. By Mr. Converse: What is your name, age, residence, and occupation?

A. A. L. Rogers; Ashtabula; carpenter; age, 59.

Q. How long have you been in the employ of the Lake Shore Railroad?

A. Twenty years, and more.

Q. In what capacity, or different capacity, have you been employed?

A. Well, sir, I have been employed as repairer of bridges; I have frequently had charge of building-gangs.

Q. State what time?

A. My first work for them was as carpenter.

Q. Within what years?

A. Twenty years ago; I don't recollect, without reckoning; but worked under Mr. Jesse Stow; Mr. Jesse Stow was then the foreman carpenter.

Q. How long did you work for them as carpenter?

A. Two and one-half years.

Q. What next did you do?

A. Repair bridges.

Q. What kind of bridges?

A. The bridges along the road.

Q. Did that include iron bridges?

A. There were no iron bridges; they were all wooden bridges.

Q. How long were you engaged in the repairing of wooden bridges?

A. About ten years; eight or ten years.

Q. What then was your next employment after that?

A. Put that at eight years; I was then put at getting out wood, at Willoughby, a short time.

Q. Do you mean firewood? What kind of wood?

A. Railroad wood, four feet long.

Q. Firewood?

A. Yes, sir.

Q. What was your next employment?

A. Put up Ashtabula iron bridge. In the meantime, whilst at that I had put up trestle work, or false work, to raise this bridge upon, and had assisted at other work around the bridge; that is, the stone work, I have reference to.

Q. What then did you do, after putting up the Ashtabula bridge?

A. The union depot roof at Cleveland, as raiser, after completing the Ashtabula bridge.

Q. What next after that?

A. As carpenter of the Toledo division.

Q. You were engaged, then, in getting out firewood for the company at the time you went at the Ashtabula bridge?

A. I think that I was.

Q. Had you ever had any experience in iron work, or the raising of iron structures before that?

A. Not in the least.

Q. I will ask you to state whether the pieces of this bridge were marked so as to designate the place that each piece was to go to?

A. Not all; not wholly.

Q. What ones were not, and how?

A. The lower chords were all marked up with pencil and paint, the course and those that went into the different courses, so there could be no mistake about it. The angle blocks were all marked in that way, commenced at one end and going through both, above and below the brace; upper chords were all marked. I feel confident that every one of them were marked. The braces were not marked, to my recollection; I don't recollect that there was a mark on any of these braces; neither were the upper floor beams; neither were the laterals marked, the sway rods, or strain rods, or the struts; all the stirrups that held the floor beams, nothing of that kind was marked.

Q. Were the stirrups marked that held the braces together?

A. No, sir; I can't say that they were. There was a man sent from Cleveland that had worked under Mr. Congdon, to point out those things to me.

Q. Who was he?

A. I think his name was Carpenter, that worked in Mr. Congdon's shop. We are speaking now of putting up the bridge the first time, before it was modified.

Q. Yes, sir. What was the first thing that you discovered wrong about the bridge or the parts of it?

A. The first thing that I discovered wrong about the bridge in my own mind was the braces bending, when we came to take the blocks out, from its bearing.

Q. Did n't you first discover that the upper chord was too long?

A. Oh, excuse me, I did; yes, sir; that the upper chord was too long, not the whole, but members of the upper chord were too long; they would n't go in between the lugs in the angle blocks, because they were set in these braces before that upper chord was put on. I do n't say that all the braces were in position; but the outside had enough to hold them in position in connection with the timber work or false work.

Q. How much too long?

A. I can't say precisely; but I think not far from a ½ inch for each member of the chord; they would n't go in. I laid the case before Mr. Stone in his office (I think it was there), and he and Mr. Congdon had a conversation upon the subject; and they planed all the lugs of the angle blocks, which would be the same as shortening the members of the chord; but I am of the opinion that they planed them off as much on one side as they ought to on the two sides. I think there was a mistake in them from the fact that when we come to put it up, we were obliged to put up what Mr. Congdon termed liners.

Q. You spoke of angle lugs, or large heavy lugs, which the members of the upper chord rested?

A. Yes.

Q. Will you state whether any of these bars of the upper chord were shortened also?

A. I do n't know that they were.

Q. Where was this planing of the lugs done?

A. At Cleveland.

Q. They were sent back to Cleveland?

A. Yes.

Q. And the planing was done there?

A. I suppose so.

Q. When they were returned to you, then what was done?

A. We put them right back in their places where they had been before, each and every one in its place on the same bearing.

Q. State, then, whether you found then that the upper chord fitted.

A. We found when we put it all together, and screwed it up, that they were then a little too short. Then Mr. Congdon, or some one else did, furnished those liners that was set in between.

Q. I will ask you, whether these thin plates that were set in at the ends of the bars in the upper chord are sometimes called shims.

A. They are.

Q. How many of those were put in?

A. That I can't tell.

Q. Will you state to the committee when you had put the upper cord in place, after it was returned from the shop, you then let the bridge down on its own weight, or partly so, before putting the shims in?

A. I think we did, sir.

Q. Do you remember what camber was intended to be given to the bridge when it was first set up?

A. It was about 3½ inches. If you will allow me to explain: At the time I put up this false work, was n't aware, did n't know how much camber there was in the frame of the bridge. I did n't know any thing about it. I went to Mr. Congdon to inquire. I knew nothing about the framing of the bridge; and I had not seen it—only the pieces, here and there. I went to him and inquired about it. He told me that he thought that it would be from five to seven inches—not to be particular. I told him I knew nothing about it, only to put this frame in. You understand, it being of such immense heft, that we could keep it only in its position. It would be much easier for us, then, to keep it into position by screwing or jacking it up. About the time this false work was completed, Mr. Stone came on to the old bridge. I told him what I had done, and he said, "You have got too much camber. The bridge is not designed to have so much camber as that. The camber of the bridge is one-half inch to the panel, or a shade less." I then changed its bearings back, plained them, and jacked them off, so as to get them as near right as I could, and then went to work to put it on, so that the camber must have been three and a half inches.

Q. State whether, when you first let it settle after putting the chords into position, it settled so far as to become concave instead of convex.

A. Not immediately—no, sir. When it came down on its bearings it had camber one and one-half inches; perhaps not quite as much.

Q. Why did you not let it remain?

A. I wasn't satisfied with it.

Q. Did you take out the false bearing then?

A. We did take out the false bearing—the bearing blocks; they were set upon wedges, so it was an easier matter to drive them out, and it settled down an inch in twenty-four hours; from where the bridge was swung it had settled an inch, and the braces began to buckle, or bend. After—I think—a week or ten days I went and started those wedges back again, and let it down, until I was satisfied it wouldn't hold. All this occupied, the whole of it, before there was any move made towards rebuilding it; the fixing of it, any way, occupied a couple of months or more.

Q. What, then, did you do, after you found that it wouldn't support itself?

A. I went to Mr. Stone's office, and told him about it.

Q. What directions did you get, if any?

A. He told me to go and get it up into position, and screw it up tighter, claiming the suspension rods were not screwed tight enough. I told him that I had drawn them so tight that in one or two instances I had buckled the braces by drawing the two chords together. I made that remark to him.

Q. State whether the shims were put in at the time it was raised—before or at that time.

A. The shims were put in before all this happened; the shims were put in immediately after it began to settle; then I fixed it on my own responsibility, or that I assisted Mr. Congdon. I think I went with him, and the shims were made, and sent me, and I put them in. I ought to go back a little; that is one of them that is on the outside brace chord; they were put in like that [showing], and the other is just fitted between the lugs that were on the angle blocks, and that set in right between there [showing].

Q. Proceed to state what you did after you had that interview with Mr. Stone, the President of the company, in relation to screwing up the nuts tighter.

A. Just as he told me, and went to Mr. Congdon, and he got all the jack-screws, and got my wooden wedges sawed off three or four feet long—oak wedges; got a number—a dozen or more—perhaps twenty, iron wedges, from two feet to thirty inches long; got an amount of boiler plate to slim up our wedges; got it up to its position, tightened the rods all that we could, so much so we bent several of them, buckled several of them a little.

Q. Several of the braces, you mean?

A. Yes, I mean the braces.

Q. State what occurred now.

A. And let it on to its bearing; then Mr. Stone came there and examined it, and said I had done him a good job; that he was satisfied, and went around and looked it all through. We had not turned the braces at this time, or added any number of braces to it. Then we let it down upon its own bearing again, and it went down again just the same way.

Q. State how far it went down then.

A. Well, sir, I think it went down an inch; that I let it down by degrees; I didn't let it hang and go down all at once; I was afraid; I took out those blocks by degrees; I let it down an inch, perhaps, a little below a straight line; its camber was all out; I can't recollect that I ever measured it on a straight line.

Q. State what you then did.

A. I then went to Charles Collins one Sabbath morning, after I had got fully discouraged; Mr. Stone required time, what I was convinced that I couldn't do; I went to Mr. Collins, and endeavored to get some knowledge that I didn't possess in regard to the matter—to know what to do—and there was reason for that too; it was simply because I was afraid something might be brought to bear that would cause me to lose my position; that was one reason that I had.

Q. Well, just state more.

A. Mr. Collins came on to the bridge; he said when he started from his home, or the house where he was stopping, that he would make it a personal matter. I think these were the words that he used: "I will go with you; and understand, officially, that I have nothing to do with that bridge, either with its design or construction." He said, "I will be there at a certain time." We compared watches; I was there, and waited for him, when he came on the end of the bridge—down on to the old bridge—and he looked and says, "I think that those braces would be stronger if they were turned the other way; they are not put in right." I don't know whether he claimed that they would hold more if they were put in perpendicularly, or if they were all flat. I pressed him quite hard to give me some information; he gave me to understand that he was not the designer, and, I think, he made the remark that it was not his bridge—that it was Mr. Stone who was constructing the bridge. I then requested him to ask Mr. Stone, or request Mr. Stone, to come down there to the bridge. He did so, and Mr. Stone did come down—got on it there. I can't say that he came on purpose, or whether he stepped off of the train, or anything about it.

Q. Let me ask you right there, before you proceed to that point, was Mr. Collins, at that time, in charge of the road at that point?

A. Mr. Collins was Chief Engineer at that time.

Q. I want to direct your attention to this point, whether, at that time, he hadn't been relieved from that duty, and was employed in building on the line of the, or a branch of the, Ashtabula and Painesville Railroad—you know what I mean?

A. I can't say; I think he was acting as chief engineer then of that road, the whole line, for I declare I can't say; there might have been a circumstance in there I have forgotten. I feel very confident that he was chief engineer of the road at that time, but I can't state it positively. Mr. Stone did come there to the bridge, from some source or other, was really quite in a hurry, or seemed to be, and said, after saying other words, that he would come there again and see to it in the course of a few days, in two or three days, he brought Mr. Congdon with him, or was in his company.

Q. Did Mr. Collins come with him at either of those last visits?

A. Not to my knowledge; I don't think he did; I think there were two that came to the bridge; Mr. Collins might have been of the party.

Q. Proceed now.

A. And they examined the bridge, them two went together and I went around and showed them a little—the bagging of the braces, and, also, that the clamps at the intersection of those braces, that some of them were broken and entirely off; that rods were five-eighth rods, and some of them were bent; but they were still together, I can't say how long, but some little time, out of ear-shot from me, because I went about my other business. Well, Mr. Stone came to me and said they had concluded to change those braces from "H" to "I," and to turn them up, and to add more braces, and that Mr. Congdon would have every thing made according to directions that he gave, and he gave the directions to Mr. Congdon and didn't to me, for I wish you to bear in mind that I was simply a foreman raiser, simply to put the iron in position.

Q. What was done with the bridge then?

A. It stood there for some time.

Q. On the supports below?

A. It was keyed at this time; I had let it go down as far as I dared to; it stood there for some little time, until the braces were made and sent down—no, we jacked it up, before the braces came down, to its original position. How long it stood in that position before the iron came, it is more than I can say; at all events, when the iron came down Mr. Congdon sent a man down to chisel all the iron and braces, and they were put in; this tubular chamber was put in at the end and every thing put in shape as soon as we got it. After the iron was got ready the bridge was then set on its own bearing, and stood so; you couldn't see it settle one hair. There was no buckle to the braces after that that I ever noticed.

Q. How many braces were added?

A. There were two (2) added to the first panel; I think two to the second; I can't tell whether there were two added to the third or not; and one, I think, all the way through. I don't think there was a counter brace added; I don't think there was, but there might have been towards the centre, but I can't recollect that there was; as I look at it, I don't think it was necessary. I don't think Mr. Stone would do it. The packing or clamps that were at the intersection of the braces were all made new, made with inch rods, and new castings sent down, and new plates on the outside, wrought iron plates on the outside.

Q. Why were not those new castings used for packing?

A. That I can't say; I asked Mr. Congdon the same question.

Q. Why do you think the packing was made new?

A. Because the braces, as H braces, would receive and require a shorter packing than those I braces; the angle would be brought farther across, and I know that the rods were made new—every thing was made strong in that point of the bridge.

Q. If the old packing had been simply turned over, would the flanges of the beams been separated just the distance required?

A. I think when it was the other way it would just fit into that; I think I have mistaken that since and found they would go in just at that angle.

Q. From the inspection of this specimen here, what have you to say as to that; was not an old packing used, the flanges being brought against the lugs?

A. It is possible, but I can't hardly think it was so; I am not clear upon that point; you recollect at Ashtabula I couldn't define it. Mr. Congdon informed me they were cast new, and perhaps that is the reason why I think it was cast new.

Q. I will ask you to state whether the old packing would not have fitted exactly as this specimen? [Showing.]

A. I think it would.

Q. I will ask you whether the old packing wouldn't, in that way, have filled every space required, except they were in solid in the new arrangement?

A. Between those braces?

Q. Yes, in every direction.

A. I don't think it would, because there was only four braces in the first panel on the first half of the angle-block, and the space would necessarily cover the two feet and ten inches—would have been quite open.

Q. You did increase the number?

A. We did afterwards, yes.

Q. Was there any arrangement made for holding the braces in position on the angle-blocks, either at the top or bottom part?

A. Nothing.

Q. State to the committee whether these braces did actually slip out of position after the bridge was erected? I mean out of the position in which they were originally placed?

A. I think that upon the north truss there was one brace that slipped out of position from its original place, but I don't think there was but one. I think that this counter-brace was a trifle too short—it might have been one-sixteenth of an inch too short.

Q. Was that the upper angle-block or the lower angle-block?

A. That was at the upper angle-block.

Q. You may state whether, from the paint marks on the angle-blocks, there was a number of them that the flanges were partly off the brace blocks?

A. There was a good many of them down a little below the edge of the angle-block, from one-half inch to one-quarter.

Q. State whether the chipping of these lugs of the angle-blocks was called to the attention of Mr. Stone.

A. I can't say that I called his attention to it.

Q. Did Mr. Stone or Mr. Collins, or other engineers and bridge builders, examine the work after it was finally raised the last time, and what did they say in relation to it?

A. After it was finally finished and completed?

Q. Yes.

A. Mr. Stone was there and said it was well done, as he had said before, and told me that he had another job for me in Cleveland, and wished I would come to Cleveland on a certain day.

Q. What inspection did he make there?

A. He went through the bridge and seemed to look at it critically.

Q. Who else did?

A. I don't know whether there was another man or not.

Q. Did Mr. Collins examine it?

A. Not with Mr. Stone at that time.

Q. Did he ever examine it?

A. I never saw Mr. Collins on the bridge whilst I was connected with it in any shape or form, except going across the old bridge looking at it.

Q. I speak now of the test.

A. I wasn't there at the test. I was putting up the Union dêpot roof at Cleveland. I wanted to go, but I couldn't be spared from putting up the roof.

Q. You have noticed, since the wreck of the bridge, that the cross-ties between the bottom of the chords were at every other panel?

A. Yes.

Q. Trusses?

A. Yes.

Q. And across the strut in the center?

A. Yes.

Q. I want to ask you now if you made a mistake in putting up the angle-blocks?

A. We supposed we did until day before yesterday, and did suppose it was a mistake made until day before yesterday. We commenced at the west end, so that we raised the west end out of the water. At the north chord we found the first full angle-block. We had one number two when we were at work at the easterly end of the bridge, where the first strut went, which you all recollect, that the bridge was locked so we could make nothing out of it, and at that first full angle-block commenced the lateral strain rods, and that they skipped number three and came in again on number four, which made it different from what we supposed. We called Mr. Williams's attention to it, and he seemed to be very much relieved that there was not a mistake; but Mr. Congdon, who was east, supposed there was a mistake. So we were satisfied that we didn't make a mistake.

Q. I will ask you whether you have examined the original plan as made by Mr. Tomlinson, and whether that doesn't show that these rods were to fasten at the end of the strut?

A. I can't say that I ever did, except when I was before the coroner's jury, and after I had testified a while they produced it to me and asked me if I ever saw it. I told them no. There was no plan given to me when I raised that bridge, only what little information I got from Mr. Congdon.

Q. If these angle-blocks were numbered at the shops, was there any possibility of your making a mistake?

A. It was impossible to make a mistake—they were numbered with pencil and paint.

Q. State to the committee whether the angle-blocks would not determine the question as to whether these rods were to cross the middle of the strut or go over the end of the strut?

A. Not necessarily. So far as the sway rods and the upper strain rods were concerned it would certainly.

Q. Do you remember whether the panels were the same as the panels in the lower chord?

A. Yes.

Q. All the way through?

A. Yes.

Q. From that fact I will ask you to state whether there could be any mistake in the putting up, or simply an error in the design of it, if there was an error about it at all?

A. I don't understand you.

Q. I will ask you whether there were not places in the angle-blocks—nitches and holes with threads to receive the bolt fastening the cross ties—the sway rods?

A. Yes, there was.

Q. And now I will ask you whether there were the same nitches and holes in those blocks where there was to be no sway rods?

A. There was not.

Q. Will you answer the other question which I put, whether there could have been a mistake in the putting up that part of the bridge, or whether, in fact, it was an error in the design?

A. It couldn't have been a mistake on the part of the raisers, from the fact that they were numbered.

Q. If, then, the angle blocks were correctly placed as originally intended, could there possibly have been a mistake, so far as the erection was concerned, in the cross-ties?

A. There could not.

Q. I will ask you whether you were back at the bridge from time to time, after it was raised, before it broke down?

A. I don't think that I passed over that bridge, after it was completed and tested, for over a year.

Q. I mean in after years.

A. Oh, four years ago.

Q. I will ask you if you noticed then and since the wreck that those braces had worn the angle blocks, some of them a small fraction?

A. I have, since the wreck.

Q. How many angle blocks have you noticed with wear marks on?

A. Will say three or four.

Q. What does that indicate to your mind?

A. It would indicate a little motion to the brace—a little loosening of the brace.

Q. What is the cause of the wearing at the centre brace?

A. That those clamps were not drawn tight enough together—that is, the side braces.

Q. Would not that show that they were working—that the braces were working?

A. It would.

Q. I will ask you whether, in your judgment, a bridge is likely to be safe for such a span as that, constructed of iron, if the braces are allowed to work?

A. Well, I don't know as it would injure the strength of the bridge—a little mite—one-sixteenth of an inch.

Q. The safety of it?

A. I don't know as it would injure the bridge—in fact, in wooden bridges they get loose sometimes.

Q. In those bridges there is always a dowel pin to hold it in its place?

A. It would probably have been better if they were perfectly tight.

Q. Would that looseness, when a train would run over the bridge, be likely to create a snapping sound or cracking as a train came on to the braces or toward it?

A. So far as that is concerned, it would give it a lateral motion.

Q. Some engineer told us that when he came on to this bridge he had observed a snapping sound. Would these braces come against the angle blocks, or the motion against these stirrups in the centre, account for that noise?

A. It may. I don't think there was play enough to injure the bridge one-half.

Q. Was there play enough to create a noise when the train was running on it?

A. I don't think there was.

Q. I will ask you to state whether the general impression among the road hands and the employés of the road was not that this bridge was unsafe, and was not what it ought to be?

A. I never heard any one connected with the road doubt the strength of that bridge. As iron does crystallize, I have heard men say—fishermen, and men that would be around the pump-house———

Q. When was that pump-house built?

A. Last year——say that the span was too long—countrymen that would be on skating parties—and they were men that had no idea about bridges, and didn't know the difference of one bridge from another; and a great many have told me at the end of a certain time that the iron would crystallize and the bridge would become worthless and the bridge would go down.

Q. I will ask you whether, on the west abutment, any considerable rock broke off?

A. It did.

Q. How near to the top was it?

A. I think it was at the second course where it commenced. It was crumbled.

Q. Do those marks on the top show as if made by the force of drawing back?

A. That was the conclusion I came to after the morning of the accident.

Q. What quantity of rock was knocked off?

A. I can't state the amount.

Q. Was it six or eight hundred pounds?

A. Oh, yes; half a ton, in all, that was there.

Q. How near to the west abutment was the second engine after it had gone down?

A. About one hundred and twenty-five feet, it might have been, one hundred and fifty feet from the west abutment from the———

Q. I am speaking when that went down.

A. I think it was from six to four feet.

Q. How did the tender and engine lie?

A. The tender laid nearly bottom side up. It didn't lay what was termed an even keel, it laid end for end. It laid on an angle with the bridge say from ten to fifteen degrees.

Q. Was the front of the engine, or cow-catcher, extended in a line south-easterly from the bridge?

A. North-easterly.

Q. Then the hinder end of the engine was at an angle of say fifteen degrees in a south-easterly direction from the bridge?

A. Yes.

Q. How soon were you at the fire?

A. I think ten or twelve minutes.

Q. Where were you?

A. In my own house.

Q. How far is that away?

A. Not far—from ten to eleven hundred feet away.

Q. What was the first notice?

A. The first notice that I had was my wife hallooing "O my God! there is a train off of the bridge!" That was the first notice that I had. I had felt a jar, and knew that there was something the matter somewhere.

Q. You felt a jar at your house?

A. Yes, plain and distinct, sir.

Q. And then your wife immediately cried out?

A. In a half minute or so. She ran to the door and as she opened the door she heard one of her neighbors, who had discovered it first; they were screaming; they lived right across the street; heard them hallooing, "there is a train off at the bridge," and she repeated it to me.

Q. And then you ran immediately to the bridge?

A. Just as quick as I could.

Q. Was there anybody there before you got there?

A. I think there were three or four men when I got there.

Q. What were they doing?

A. The first person that I recognized was the conductor; I saw two persons; they seemed to be assisting some person on the ice.

Q. Was that the fireman that had been down there?

A. Yes, sir; and the conductor was striking a blow with an axe, and seemed to strike wild; he didn't strike solid anywhere; and another man catched the axe from him, and the first blow that he struck, broke the handle inside of the axe.

Q. Was the wreck on fire when you got there?

A. It was.

Q. How far did it extend?

A. There was fire in five places.

Q. How far from the line of the bridge?

A. There was a fire in the westerly end—south-westerly end.

Q. Locate it as between the abutments of the bridge.

A. There were two fires near the west abutment; somewhere near the center there were two fires, they were not very large; and then near the east abutment was a large fire, blazing up ten or fifteen feet high, when I got there.

Q. There was screaming, and noises, persons crying for help, when you got there?

A. My first impression was, that there was no life in that train.

Q. How long was it, did you hear the screaming?

A. It might have been a minute.

Q. How long was it before the train was wrapt in flames?

A. Not to exceed twenty-five minutes.

Q. Do you mean from the time you got there?

A. Yes.

Q. How long was it before the engine or hose cart got there?

A. I saw a hose cart, after I got there, assisting in getting the wounded out, and getting them up the bank; then in order to facilitate in getting them up the bank, a man from Tennessee, Mr. Wright, said, "hain't you got a rope?" and I ran to my shop and got a rope; at that time I saw a hose cart, and it was the fire apparatus that I saw that night there.

Q. That belonged to the town?

A. Yes, sir.

Q. There was no hose belonging to the company?

A. Not to my knowledge.

Q. I will ask you if that fire could have been put out or smothered at any time after you got there, or at any time after any engine came?

A. If the fire department had been there at the time, my impression is that fire could have been put out in ten minutes.

Q. How far did the fire engine have to go?

A. A mile, or more.

Q. What have you to say as to the condition of the roads on that night?

A. They were simply horrible; drifts as deep as your waist—four feet.

Q. How deep was the snow on a level?

A. Probably two feet.

Q. Had the road been broken up to town?

A. Teams had been passing.

Q. Had it been snowing, that day?

A. Yes, and drifting during the day; as hard a snow as ever I had experienced.

Q. As far as you know, or been able to hear among the citizens in the town, whether there was any declination on the part of the fire department, or any one, to throw water, to save life?

A. I have simply heard that there was; without knowing, I don't know personally.

Q. Do you know how many got out alive?

A. I have been told, sixty-eight.

Q. Can you tell whether these cars were smashed up in going down?

A. They were a good deal broken, but not so much as I should suppose.

Q. How many, do you think, perished there?

A. I think in the vicinity of seventy, according to reports. On Saturday evening a gentleman came to me and said he was a reporter, and wished to go through the freight house where the dead bodies were that had been burnt, and were deposited in boxes that my carpenter had made; he requested me to go through with him, that they wouldn't let him in, unless he had a pass or some one with him. I had been back and forth all day, and we counted forty-eight, what we considered remains, in those boxes.

Q. By Mr. Stone: That was on Saturday?

A. Yes.

Q. By Mr. Brown: At what time on Saturday?

A. I think it was three o'clock in the afternoon, and it might have been four.

Q. By Mr. Converse: I simply ask your judgment, from what you saw at the wreck.

A. I saw sixty-five or seventy; it is guess-work.

Q. By Mr. Haynes: How do you think the storm distressed the bridge, if any?

A. I can't say. It must have affected that bridge wonderfully. It must have been a great pressure this way. [Showing.]

Mr. Rogers recalled.

Q. By Mr. Converse: Have you thought of any thing you would like to state since yesterday?

A. Yes, sir. Every one of the sway rods were broken in the screw, where the screw was cut, were broken, except one; the lateral sway rods were broken that I have discovered in the screw and turn-buckle; and they were broken, all of them that I discovered, in the thread that screws these in. In the whole rod they were an inch and a quarter, and then they were cut down to five-eighths.

Q. By Mr. Brown: What would that indicate as to the power of the iron?

A. That the rod was not as strong.

Q. You think that the thread ought to have been cut right on the face of the rod?

A. I think on every rod where there is a screw should be upside, so that the one end of the thread, where it is cut in, should be as large as the rod was anywhere else. Such was not the case.

Q. By Mr. Converse: Your statement is that they all broke?

A. All that I have discovered.

Q. By Mr. Brown: Did you think they were broken before the bridge cracked?

A. I can't state that..

Q. Did you examine into the iron?

A. Now, as far as that was concerned, they were burnt in the wreck, and we couldn't tell. If they had broken before the wreck, it would certainly have been discovered. It might have been broken at the time by some train. Had it got a pitch of one inch, in my opinion, it would never have come back.

Q. By Mr. Converse: Is there any thing else you would like to state?

A. I don't know that there is; I can't think of any thing further.

Q. There is one question I would like to ask for my own satisfaction. Why was it that Mr. Collins was so unwilling to have any thing to do with this bridge? What is the inner history of that thing?

A. Is that in testimony? If it is, I am obliged to answer you that I don't know any testimony.

Q. From whom did you get orders to proceed to put up the Ashtabula bridge?

A. It came from Mr. Stone, through some person, I don't know whom.

Q. State whether it was in writing or verbal.

A. I think it was a verbal order.

Q. Did you get any written order to proceed to put it up?

A. No, sir.

Q. By letter?

A. No, sir; not to my recollection.

Q. You may state whether any engineer was employed to superintend the erection of that bridge.

A. There was none. Remember, gentlemen, that I am speaking entirely of that iron bridge.

Q. Under whose direction was the trestle-work erected on which the bridge was erected?

A. By Mr. Collins.

Q. You may state whether Mr. Collins superintended the trestle to be used in the erection of the bridge itself.

A. Well, yes, I may say that he did, because he looked at it, and said it was a good, strong job, and pointed out the timber that I should use. This timber was in his department, and I was to take that particular amount of timber. It was furnished by him. I can't say it was all sent to me to be put up there. I don't know as he gave me any diagram, or any thing of the kind, but it was a good, strong job.

Q. I will ask you, now, whether anybody, so far as you know, had any thing to do with the project or planning of the bridge or superintending of its erection, except Mr. Amasa Stone?

A. Well, not to know personally. Mr. Amasa Stone told me, in connection with that bridge, one day, that Mr. Tomlinson had proved inefficient, and he had discharged him, or something to that effect.

Q. Was Mr. Tomlinson discharged before you commenced putting up the bridge?

A. Yes.

Q. Did any other engineer or person, so far as you know, have any thing to do with the planning of the bridge, except Mr. Stone?

A. Not to my knowledge.

Q. Did any engineer have any thing to do with the erection of the bridge and putting it up in place except the directions which Mr. Stone gave you from time to time, of which you have testified about?

A. No, sir.

Q. How frequently did Mr. Stone come there himself to look after or superintend the erection of the bridge. I mean now the setting it up?

A. Mr. Stone was on the old bridge, standing upon the wooden bridge when I was first getting down the members on the lower chord; as I stated yesterday, that was the first time I ever saw him there. He was there again once when we had got the bridge nearly completed, at this time he came on to the bridge, he staid a very few minutes, he came down to the iron bridge through the walk which we had.

Q. Did he make you any other visit until you sent for him, as you testified yesterday, by Mr. Collins?

A. Yes. He did.

Q. State when?

A. It was when we had got the bridge completed, so far as the bridge proper was concerned; he came there and looked at it, and said it was together right, and that it was now ready to swing, and we knocked out the blocks.

Q. You have stated that you didn't know why Mr. Collins didn't superintend the erection of the Astabula bridge. I will ask you, whether there were any reports in the neighborhood on the subject, and if so, to state what they were?

A. Yes, there were such reports.

Q. Just state.

A. Such reports among my class, and men that were on the road that were connected there with me, wondered why Mr. Collins or some other competent engineer, was not there to superintend it. I can't give it any better language than that, I say these things were a fact in regard to this matter.

Q. State whether Mr. Collins, had always been particular about always having good and substantial work on the road?

A. Extremely so. Extremely particular.

Q. How long have you been connected with Mr. Stone?

A. I have known him for over twenty or twenty-one or twenty-two years, and to say that I am acquainted with him to-day I can't.

Q. I will ask you to state whether he would allow Mr. Collins or any body else to to make any opposition to his will or his plan?

A. I don't believe that he would.

Q. Or any suggestions?

A. He might possibly receive a suggestion. From the little that I know of the man, I don't believe he would even receive a suggestion, he might. I can relate a circumstance that might modify that statement, but I wouldn't like to give it in testimony.

Q. State whether Mr. Tomlison was discharged before you began the erection of that bridge or afterwards?

A. He was discharged before, I am informed.

Q By Mr. Brunner: Do you know the reason why he was discharged?

A. Only that I have understood that there was some misunderstanding between him and Mr. Stone, and Mr. Stone claimed that he was incompetent. I never saw Mr. Tomlinson at the bridge since the wreck.

Q. Did you understand at the time, what the misunderstanding was?

A. No, sir.

Q. By Mr. Brown: You saw his testimony?

A. Yes.

Q. What did you think of it?

A. There was some of it that wasn't as I had supposed.

Q. Mr. Converse: What is your opinion as to whether the sway rods broke before the bridge came down or when it came down in the fall?

A. I believe the sway rods were broke and caused the bridge to fall.

Q. By Mr. Barrett: They were the first that gave way.

A. I believe they were the first things that gave way.

TESTIMONY OF JOSEPH TOMLINSON.

Joseph Tomlinson, civil engineer, being duly sworn, testified as follows: (Testimony taken before the coroner's jury at Ashtabula.)

Q. What is your age, occupation, and residence?

A. I now reside in Ottawa, and am general superintendent of light-houses, Canada; I am a civil engineer; my age is between sixty and sixty-one.

Q. By Mr. Hall: How many years have you been engaged in the profession of civil engineering?

A. It is difficult for me to say. I came to this country in 1840; am a mechanic by trade, and took to bridge building as a matter of choice. I was employed on the Housatanic Railroad as a road man.

Q. How many years have you been engaged in the business of bridge building?

A. I think from 1846 to 1870.

Q. How extensive has been your experience in that department?

A. I suppose some years. I built thirteen or fourteen bridges each year as contractor for bridges, and perhaps more. I have been civil engineer for some very large bridges.

Q. What large bridge do you now remember of?

A. I rebuilt the suspension bridge, as one, after it was blown down many years ago —in 1857, I think—and it is yet standing; extends 630 feet. I built one in 1854, 250 feet over Hammond river. I had a letter last week which told me it looks as good as it did the day when I left it. I have not seen that bridge since I built it. For some years past my experience has been more on bridge foundations than on superstructures.

Q. Had you any connection with the drafting, designing, or construction of the bridge at Ashtabula which has lately fallen?

A. I was employed by Mr. Stone to make the drawing for this bridge.

Q. Will you now state in detail, in your own way, the connection you had with that bridge in any manner?

A. I made the plan under the instruction of Mr. Stone. I mention this because I never approved of a wrought iron Howe truss. It makes a much heavier structure, having the principal braces in compression than what they would be if made to act by tension. And another objection is that all the strain accumulates on the end of the brace. Still, notwithstanding that the structure was necessarily heavy, it was intended to be a very strong and permanent structure, and would have been so if the main braces of the bridge had a section in proportion to the tension of the members. When I made out the calculations of the bridge I had instructions from Mr. Stone to proportion the structure so that it would be four tons on the square inch in tension, and four tons on the square inch in compression. That proportion made the tension members much stronger in proportion than the members in compression. When the bars—the H and I bars—were rolled for these heavy members the section on the larger bars, for the main braces, were not made as large as originally intended. That was the main defect in the construction of the bridge. And I also expected, if I had been employed to carry the work out, that those braces, the main braces at the end of the bridge, would have been strengthened or additional bolts riveted to them. When I was doing business with Mr.

Stone, in my interviews with him about these matters we never could harmonize. Whenever I made any suggestions it always led to some discord, and it was these circumstances that I left the work. I would state further that the bottom chords of the bridge, the tension members, were as good work as ever I saw made. The top chord was sufficient for all purposes. I may add here that when it was laid out by me, it was laid out calculating for six-inch camber, so that when erected a principal part had taken its bearings, it would still have about three and a quarter or four inches camber. That was my calculation. The substance of this is that the main braces of the bridge were the only defective members in the bridge. Mr. Stone knew it, because we had several conversations on the subject. They were defective in this, that they were too small—they had not sufficient section—they couldn't fill the section when they rolled them in the mill. That was the only defect that I am conscious of in the structure except this unnecessary weight. I don't know how much it was calculated that each truss should carry to the foot, but I think it was a ton and a quarter or a ton and a half. It is many years to remember. But it was intended to be an exceedingly strong structure. This was Mr. Stone's intention, and the intention of others. It was intended to be an exceedingly strong structure, and was all proportioned except the defect which I have mentioned, which was the deficiency in these bars, which formed the main braces.

Q. So far as you know, was this the first application of the principle of Howe truss bridge to iron bridges?

A. Oh, no; there have been a great many built with cast iron members in the place of wrought iron bridges, but not by me, though.

Q. Where was the iron work for this bridge made?

A. At the Lake Shore shops, Cleveland.

Q. Did you superintend this work?

A. Yes, sir; I gave the patterns, and the length of every part of it, for the mechanics to work by; and gave them correctly, though it has been reported to the contrary.

Q. Did you also inspect the work, and did you know whether those plans, as furnished by you, were strictly followed?

A. They were followed as long as I had the superintending.

Q. And did you have that superintending until the same was completed?

A. Very nearly.

Q. What parts, if you are able to state, were not completed at the time when that superintending ceased?

A. There were patterns being made by the pattern-makers which I didn't see finished; but the chords were made; and the bottom chords, which were the most important part of the structure, were all finished.

Q. For what part or parts of the bridge were these patterns designed, that you didn't see finished?

A. I have only a kind of indistinct consciousness that the pattern-makers were making some patterns which were not finished, and which I didn't see what they were. The surface of the angle-blocks were not planned, and there were some little things not finished; but it was nothing essential.

Q. Had you any thing to do with the superintending of the raising of the bridge, as it is called?

A. No, sir, I never was; I don't think I ever was on the site of the bridge at all, except to pass over it.

Q. In your employment in regard to that bridge, had you any instructions from, or was it, if any, superintended by Mr. Charles Collins?

A. Mr. Charles Collins might have taken a little interest in the matter, but he didn't have any superintendency or authority over it; it was all directed by Mr. Stone.

Q. Had you, at the time, knowledge of the fact that the bridge, after being raised, was taken down, and the position of the braces changed?

A. I think there is some misunderstanding about that; my understanding of the matter is this: that after they began to put the bridge up here, they found that the top chords were longer than the bottom, and the bars were all sent back to Cleveland and shortened; then when they put the bridge up they found that the bridge was below level. That had to be taken apart, and a piece of plate of iron inserted to make up for what they had taken out. That was hear-say at the time, and I have been down to the bridge to-day and examined, and have found it to be the fact, that there was a piece of boiler-plate inserted at the end of the beams that formed the top chords.

Q. In your design, were the braces intended to rest flatways, or upon the edge, with the weight horizontal or vertical?

A. I shouldn't have particularized that, to be positive, until I went down to the bridge this morning. They were intended to lay flat, in the first place, and they were changed to stand edgeways, and when the bridge was erected, I was informed, I can't tell by whom, I can't remember, that the beams with small sections were used for the end braces, that made this change in the direction of the brace necessary, so as to get in a greater number of braces. I learned this morning for the first time, that there was a greater number of braces put in.

Q. Was the bridge, so far as you know, correctly set up, and if not, wherein was any incorrectly set up or raised?

A. Personally I know a little about raising a bridge; what I have told you was hear-say; I was, moreover, told that the stretchers for the lateral bracing of the bridge were in place at the end of the lateral tie braces; they were placed right across the middle of the lateral bracing, and, as a consequence, they would have very little effect. Those were the only things that I have heard were wrong.

Q. Have you, since your arrival here, examined the wreck of the bridge, to ascertain whether that information was correct?

A. I have been down at the bridge, and about the lateral bracing I could tell nothing; I tried to find out, but there was no particle left to show how the arrangements were; the pieces between the top chord beams and the angle-blocks, some of them, are still in place; by the top chord beams I mean the five I beams, side by side, which constituted the top chord.

Q. By Mr. Goodwin. During the construction of the iron work of the bridge, did you exercise a supervision over it in the shops?

A. Yes, sir.

Q. And saw and inspected all the iron work for the bridge, except those portions which you have specified as not being finished at the time when you left those immaterial portions?

A. Yes, sir.

Q. You say the unfinished parts were some angle-blocks and some little things—nothing essential, so that you actually inspected all the iron work of the bridge?

A. I inspected it so far as to see when it was done well there. I probably ought to state here, that the strengthening of the end brace was always a matter in my mind, was a matter of dispute with me and Mr. Stone.

Q. When you left the work, had there been any decision made in regard to this matter of strengthening the end brace?

A. No.

Q. It is your understanding that the bridge was erected with the members of the upper chord and the braces above the main camber, as they were shown in your own original design?

A. I always understood that the small beams were used in the main braces, and that the beams with the larger section were used in the counter braces. The beams were rolled with web bearing, in thickness from one-half an inch to, I will say, an inch and one-fourth, so that the section of those with an inch and one-fourth web would be only double those with one-half inch web. Those beams with a large section were intended for an end brace. Those with small sections were intended for an end counter brace. I understood that beams with large sections were used for counter braces, and beams with small sections were used for main braces.

Q. What information had you in regard to this distribution of members?

A. It was talked among us engineers when I was in Cleveland, some time afterward. I can't remember by whom.

Q. Can you recollect, without the assistance of the drawing, substantially, the size you intended for the braces, main and counter, that you intended to go into the bridge, giving us the size of the ends at the ends, and progressing towards the centre of the bridge?

A. Only general. That the largest sections were intended for the end braces, and that they were gradually diminished in size to the centre. The end counter braces were the smallest that there were in the bridge; and then at the middle there were two counter braces, and the section of them was enlarged also.

Q. Did you make a strain sheet for this bridge, and calculate strains for the structure according to your design, and leave that strain sheet with Mr. Stone when you left?

A. I made a strain sheet, as a matter of course, calculating strains for the bridge according to the design and the instruction I received; and I left all the drawings in the office when I left.

Q. You specify in your answer, and particularize the word "the" design. I understood you so. You wish us to understand that the design was made, as you here said, under instructions from Mr. Stone?

A. Certainly, it was made under instructions. I didn't design bridges of the same character when I design bridges to be built by myself.

Q. You say that there was a difference of opinion between yourself and Mr. Stone in regard to some detail of the design; that you had expressed your intention to strengthen them or increase the number of the end braces; that you and Mr. Stone didn't agree upon that point up to the time that you left. Is that a fact?

A. Yes, sir. You see, looking at the design as I did, and knowing that it could be made a strong structure, I alluded first that the compressive members of the structure, particularly the end braces, could be strengthened to any extent required.

Q. Do you mean that they could have been strengthened to any extent required without material change to other portions of the bridge?

A. Yes, sir, by addition of bolts riveted to them so as to connect each set of braces throughout their entire length.

Q. Would it not have been proper, in your opinion, to have increased the strength of the end braces by lengthening the end beams?

A. I think it was; and it was all changed, so far as it went; and the whole set ought to have been united, from side to side, through the whole length, and not merely at the centre, where the camber passed between them.

Q. If you had control of the construction of the bridge up to its completion, what modification in the design as originally made would you have introduced?

A. Nothing more than to take out the necessary section to have made the strain that came upon it.

Q. How would you have secured that necessary additional section?

A. By riveting bolts of iron to beams would have united them together as one brace, and, at the same time, giving all the necessary section that was required.

Q. Would you have made, provided you had had entire control of the structure, any other modifications?

A. I think not—not if it was to remain a Howe truss. My changes would only have been by changing the character of the structure.

Q. I conclude, then, from what you say, that the principal objection you had to the design was, that the form of the bridge was that of a Howe truss, and that you did n't consider it proper to build a bridge on that general plan of iron as this was built? Am I correct in that conclusion?

A. Yes. I do n't approve of the Howe truss when it becomes a large span. I don't in wood even, if a large span.

Q. Then your objection, as it appears, is to the Howe truss plan for bridges built of iron for a span as great as 150 feet?

A. Yes.

Q. You have said that the bridge was calculated to carry a moving load from 1¼ tons per lineal foot. That was, as I understood you, to be the working load of the bridge from two to three tons per lineal foot for the whole bridge?

A. Yes.

Q. What was the factor of safety used in your calculation for this bridge?

A. My factor of safety in this bridge was four tons to the square inch in tension and compression, as limited by Mr. Stone; the members in tension were stronger than necessary.

Q. By Mr. Morrison: Were the members in compression correspondingly weaker than they ought to have been, or stronger?

A. They were weaker in proportion than they ought to have been; but in this they didn't hold section—were not as large in section as they were intended to be; I mean the largest members.

Q. By Mr. Goodwin: I understood you to say that you had nothing to do with the raising of the structure?

A. No; I never was there.

Q. Then your observation of these parts of that bridge were made in the shop or at the mill?

A. Yes.

Q. This structure, which we have been speaking of, what it would have been had the design been followed, you can't say from personal observation, as I understand you, how the bridge was actually constructed or set up?

A. I never saw it; I know only from what I heard.

Q. Did you ever see the bridge as it was when it was put into use?

A. I have passed over it on the train; that is all; I never saw it only as I looked out, when I could see nothing of any kind.

Q. By Mr. Morrison: I understand you to say, that in making the plans for this bridge, you was dictated to by Mr. Stone; that your instructions were all from him.

Did you consider those instructions as reasonable, and the requirements that he made of you as reasonable and right, under the circumstances?

A. Not exactly reasonable; because in said sections is not a true method in getting at the principal sections. Four tons to the square inch in one place may be perfectly safe; in another, not safe. If the iron had been made a full section and placed in their proper position, the bridge would have been a safe bridge to-day. I should not have built a structure that I had any misgivings about. Do you understand?

Q. By Mr. Morrison: You speak, Mr. Tomlinson, of a strain of four tons to the square inch in one place as being safe, and in another not safe. In which place do you consider it safe in this bridge?

A. I think it would be safe in the top chords; because it is such a short distance between the bearings, and they are so well united together.

Q. Give any other place?

A. No, I don't know of any other place where there are short bearings.

Q. By that do you mean that the compression of four tons to the square inch would be safe in this bridge, only in the top chord?

A. Only in the top chord; because there the panels are short, and the parts that compose the chords were united together in safe places between the panels.

Q. Would you consider the compression of four tons to the square inch safe, as applied to the main braces in this bridge, as it was erected?

A. No.

Q. Let me ask then, what would have been the effect of compression upon those main braces, four tons to the square inch, as it was erected in its modified form?

A. That they would be deflected out of line; the members would have been out of their line.

Q. Do you understand, Mr. Tomlinson, or, have you in your own mind a clear idea how this bridge was erected, or set up, as modified from the original drawing?

A. Only from hearsay.

Q. We have had in evidence that the modification consisted in this, that the I beams, which formed the main braces and counter-braces, were set up edgewise—in other words, the web vertical, instead of being, as originally drawn, horizontal; that there were added, at the end of the panel, to the end of the set braces, two braces; to the next one, two; and the next one, one; and the next, one; and the rest of the bridge remained as originally planned; they were placed vertical, instead of horizontal; that these braces were secured together at their intersections by packing between cast-iron lying horizontally across the intersections; holes through the ends, and washers outside of that corresponding, holds a bolt put through at each of these places—a washer put on with nuts on the ends of these bolts turning up tight on the inside truss. This being the condition, what would be the effect, think you, upon that application of pressure, equal to four tons to the square inch, on that calculation—I mean, taking into consideration, also, the fact that this yoke, as described, around the center, was the only thing which bound them together, leaving them free for ten feet of their length for deflection?

A. It is a matter of calculation to know what the effect would be; that my impression would be it would spring out—deflect laterally; they would not crush, they would deflect out in the weakest direction.

Q. Did you, at the time of making this plan, have a conversation with Mr. Stone in regard to the section of these braces?

A. Yes. I had represented that the braces were not sufficiently large to meet the requirements; they were not large enough in the first place; they were not what the drawing represented; and when they came to be turned out from the mill they didn't hold full size, as intended.

Q. Did you, at that time, say to Mr. Stone that to secure the resistance of compression of these braces the I beams must be increased, either in numbers or size?

A. My proposition to him was to increase their strength by riveting plate to them; I had suggested to him that they were not strong enough.

Q. By Mr. Pettibone: To what extent was the strength of those I beams—the pieces composing the main braces—impaired from the fact of their having been rolled improperly?

A. It is very difficult to state to what extent; I can't remember, now, how much the deficiency was, but it was a serious fact—so serious that several ought not to have been used.

Q. By Mr. Morrison: You say you suggested to Mr. Stone that further security and strength should be given to those braces by putting on a plate of iron?

A. I suggested to have a plate that would unite the first set of main braces—two or three sets—with these braces, side by side; and when I suggested any thing of this kind to Mr. Stone, he was wrathy, and would not hear, so that I would be driven from his office; and it was under these circumstances that I determined to leave him. The interview about the braces was on one day, and the next day, when I went into his office on some other business, he was so insulting to me that I went up to the office and resigned.

Q. How long a time did this take place before the work of preparing the bridge to be put up took place?

A. It was a month or so after I left before the raising of the bridge was commenced—before they made any attempt to raise it; I am not certain as to the exact time. If the braces that I had for the main braces had been put in their proper places, and the two additional members added for the main section, I think there must have been the necessary strength to have been safe.

Q. I understand from your last statement, that the braces which you intended for the main braces at the ends, were changed, and others lighter and less secure, put in their places.

A. Yes, sir, I understood so, it was told me; I didn't see it.

Q. What effect would this exchange of braces have upon the strength of the structure?

A. They would be much securer to the bearing of the strains that came upon them.

Q. When you were at the wreck this morning, as I understood you to say, did you make any examination as regards this exchange of braces?

A. I couldn't tell which were end braces; some of them had been removed and thrown upon the bank on the other side; there were none of them in position.

Q. From what you say of your intercourse with Mr. Stone while working upon the plans of this bridge, Mr. Stone and yourself didn't harmonize.

A. No, we couldn't agree.

Q. Let me ask, what were the main points of difference between yourself and Mr. Stone?

A. That is very hard to answer; my feelings were, that he didn't like to have anybody that had any opinion to give at all.

Q. What I want to get at is, what was the main point of difference between you and Mr. Stone, in regard to the construction of the bridge?

A. As far as my memory goes, I never had any anxiety, except the compressive members of this bridge. I knew that the chord rods were as good as could be. I don't think there was a better set of chords put into a bridge.

Q. I understand from that, that you had no fears, as far as the bridge was concerned, upon which the strain was tensile. And all your fears, and your anxiety, was about those parts which were in compression. What portion, or what part of the members were under compression, which gave you the greatest anxiety?

A. The three first set of braces in the bridge from the ends.

Q. By Mr. Pettibone: If, as you understand, that bridge was modified and the position of the braces changed, and the addition of other braces in the three end sets, would that in your judgment, have rendered the bridge perfectly safe?

A. If they were equal to the beams of the largest section furnished, I think that it would have been safe.

Q. But if as you understand, that beams of the smaller section were used for the end set braces, and if two additional sets of beams were added to those braces of the same size and the smaller sections were that, in your judgment, give the required additional strength and security to the bridge?

A. If they were above the middle sections, I think it was, and if they were only equal to the smallest section, they wouldn't be sufficient, and it is hardly probable that the smallest section was used.

Q. You have no personal knowledge as to which size section was used in the end sets?

A. No. I have not by personal knowledge, but it was talked about so much by the engineers, and those that were familiar with that class of work, that I have reason to think that the smaller braces were put in the place of larger ones in the first place.

Q. You have looked at this drawing here, have you? Do you recognize it? Is it your work?

A. Yes, sir. This is the preliminary drawing. The first drawing that was made of the bridge?

Q. Does that drawing show the general plan and principles upon which this bridge was constructed?

A. Yes, sir.

Q. Does it, or does it not show the dimensions of the several parts?

A. It does not show the dimensions. It is too small to show them all. The strain sheet, which ought to be with this, would give the dimension of the several parts. The strain sheet is more important than this.

Q. I want to ask you further, do you know the weight of a locomotive in use for passengers trains—in use on the Lake Shore road?

A. I suppose in the neighborhood of thirty-five tons.

Q. Is that a conjecture?

A. No, it is not. When I was on the road, that was about the weight by which we estimated, including tender with the locomotive as it would bring its weight on the bridge. I speak from memory and might be wrong.

Q. Do you know whether locomotives, at the present day, are made of increased weight than what they were at the time you speak of.

A. I should think that the express engines now, judging from their appearance, are about the same as they were eleven years ago. When I was in the habit of proportioning bridges, I knew the exact weight of them.

Q. We have had in evidence, that the bridge upon this second trial, before it was modified and put up, I understand that these main braces by the settling of the bridge by its own weight, were deflected some of them four inches, what would that have on the iron to increase its tendency to deflection?

A. I suppose they were much more readily deflected in the same direction the second time, but my impression is, that they were to be a permanent set in the length so that they would be shortened—too short to use by that over load and piece of iron, it gets a permanent set upon it, it becomes shorter or longer.

Q. To what distance could a bar or I beam, the size of this, in those main braces be deflected without producing a permanent set as you term it?

A. I don't think the could be deflected without producing a permanent set.

Q. Suppose these braces to have been put into the structure as first erected, placed horizontally and screwed tighter by the means already described, a deflection vertical of three inches to take place in those braces, would they be likely to return to their line upon the removal of this pressure?

A. Pretty near, I think; but the movement of iron under such circumstances is very uncertain. I should think they would be likely to go to their places again, particularly if the strains were on them but a short time. I consider a day a long time for it to remain under that strain.

Q. Suppose that deflection to be four inches, and to have remained or have been some days in coming on by the gradual settling of the bridge, what would be its effect?

A. After it had been deflected four inches by the end pressure I would consider the permanent deflection of it would be at least one-third of the full amount of deflection, and this only. And yet I think the strain when produced end ways, I think, would be much more, so far as it would compress the middle on one side.

Q. Would you consider it safe to take beams which had been subject to such pressure and deflection and change them from a horizontal to a vertical position, and subject them to the same pressure without having first, by some mechanical means or some other, to restore them to their original capacity to endure pressure?

A. Without strengthening them I should not consider them fit to use, because they had proved insufficient. The changing of position doesn't make much difference.

Q. We have had in evidence, with these beams and braces having been deflected, without taking out of their position changed from horizontal to vertical and yoked at their intersections, and put into position as compressive members in this bridge, with the tension of new iron, to a certain extent as already stated. What I want to ask, what would be the effect upon these braces, light pressure, or to carry a train of cars with two locomotives, the first deflection being merely from the weight of the bridge?

A. If the column had proved itself too small and too weak to carry a load, it ought to be increased so that it would be three times that strength. To get three times that strength it would not be necessary to have three times that calculation, but when put in sufficiently it would bear three times that calculated strength.

Q. If, under a pressure of a heavy train running upon the bridge running over these trusses, one truss bearing six times as much load as the other, and deflection in this main brace should occur laterally, what, in your opinion, would be the effect upon the bridge?

A. If any serious deflection took place in one of the braces it would change the relative bearing force on the truss so as to bring them very much on the outside members of the structure. The question is one to which I couldn't give a positive answer, but as far as my experience goes I would have thought that that truss would have yielded a couple of feet before it would have gone down.

Q. If the truss had yielded two feet in consequence of this deflection outward or inward, or both main braces, would it have stood there with a strain on it?

A. I should have thought that the deflection of the braces would have allowed the truss to settle two feet before it would have gone down, so as to give time for the train to pass, or that the fracture wouldn't have taken place certainly. Wrought iron doesn't break suddenly. There is a gradual yielding; something has to snap before it goes down.

Q. With that statement, suppose these braces to have given way—I understand you, then, to be because at first there would be a gradual settling of the roadway and the train upon it was moving across it, for two feet or perhaps more, you thought likely to continue until the bridge went down?

A. The movement of the deflection would be sufficient still, in my opinion, to allow the train—I think there would be sufficient warning given to allow the train to get off—sufficient time for it to get off.

Q. Suppose the lower chords of that bridge had parted—all the chords—what effect would that have upon the bridge?

A. It would go down as quick—just as quick as a bow would fly up when the string was cut. If it were so there would be evidence of it, as the braces would cause the ends of the lower chords to strike with force against the abutment.

Q. I understood you to state, I think, in the first of your evidence, that the tensile portions of the bridge were stronger or heavier than they ought to have been; by this what portions do you mean?

A. I mean that the tension members, if they had been secured down, would have been strong enough to crush every brace in the bridge. They were exceedingly strong truss rods. The vertical rods in the bottom chord are the tension members of the bridge. The compression members are the upper chords and the main and counter braces.

Q. Do you know the weight of the iron used in the construction of this bridge?

A. I did know, but I don't remember. It was all estimated up at the time, but I don't remember.

Q. Do you know who furnished the iron which went into this bridge?

A. The iron was brought from the Newburg mills. Mr. Jones was the foreman of the mills at the time—I think his name was Jones. The quality of the iron for the tension bars was all good. It was worked under my eye, and I know it to be good. The compression members did not have to be so good. It isn't usual to put the same quality of iron in compression members as in tension members. It isn't usual or necessary to do so. The iron that is to be in compression is usually a harder iron, and that is just as good for compression as it would be to put in the best of refined iron.

MONDAY MORNING, *January* 15, 1877.

Q. By Mr. Morrison. On your examination on Thursday evening, 11th inst., it was understood that you were to go to Cleveland and, if possible, to obtain the strain sheet and working drawings of this bridge. Did you find them, or have you seen them?

A. I couldn't find them.

Q. Did you apply to the officials of the railroad for them?

A. I did, particularly to Mr. Collins, and he told me that they had hunted thoroughly in his office. Mr. Newall told me that they had made a thorough search of the shops, and went down to the shops and saw Mr. Haywood, who had charge of the pattern-making there, thinking he would be likely to know; and he said he made a thorough search and couldn't find any thing that belonged to the bridge. That is all the search I have made about it.

Q. Did you undertand that any inquiry for this strain sheet and working plan, were made of Mr. Stone?

A. I didn't hear any thing of the kind being made.

Q. Did any one propose to inquire of him?

A. No, sir; if I remember right, when I left Mr. Stone's employment I was told to hand the plans over to Mr. Collins and the work over to Mr. Congdon. I am not surprised that these working plans were not found; because we set no store by them, when the work is done, it is not expected that any thing will come up that will require them.

Q. Did you learn, in your visit to Cleveland, any other material facts in regard to the construction of this bridge?

A. No, sir.

Q. When did you return from Cleveland?

A. This morning.

Q. Did you visit the wreck of the bridge immediately after you retured from Cleveland?

A. Yes, sir.

Q. Did you give it a thorough examination, as much as you could in the time you have had?

A. Yes, sir.

Q. Did you examine, Mr. Tomlinson, as regards to the bearings of these main braces and the counter braces upon the angle blocks, to know whether they were in place; can you tell?

A. On the south truss, I think I can find but one or two angle blocks; examined all that I saw, belonged to the north side, except one or two, on one of the angle blocks especially, there was evidence that one of the braces was fully three inches out of place when it was last painted; this is on the north truss.

Q. How about the angle blocks that you found belonging, as you believed, to the south truss? Did you find indications that the braces were out of place?

A. Slightly; so much so, that the lower flange of one or two braces were completely off of the angle block.

Q. In the modification of the bridge and change of the position of the main braces from horizontal to vertical, did it require a larger surface to the angle blocks to receive the head and foot of the main braces?

A. The same number and size; the braces would only require the same surface; but if the number was increased, then it would require additional surface for these extra braces.

Q. The faces of the angle blocks on this bridge were originally intended to receive I beams, six inch web and four and a half inch flange, lying horizontally; now, by turning those bolts and setting the web vertical and the flange horizontally, would there be breadth enough on the face of the angle block to receive them?

A. There was width enough on the inclined surface of the angle blocks for the six inch braces in place, but any where they interfered with the bolts.

Q. Did you notice what measures were taken to remedy the deficiency, where the bolts were interfered with?

A. Yes; a number of the flanges of the braces had been cut away.

Q. How many of these braces had been cut or chipped, more or less, in order to accommodate the bolts?

A. I couldn't tell; but I should think about two in five.

Q. What effect would this chipping away have upon the sustaining power in those braces?

A. Cutting away a corner, slightly, I don't think it would have very great amount, any dangerous effect; but when the flanges are cut away on one side so as to leave only the web and the flange on the opposite side, it would render the braces less stiff; it would very much impair its strength.

Q. I think you spoke in your first examination, you mentioned that upon the face of these angle blocks, there were lugs cast, into which the heads and foot of the braces were introduced to keep them in position. Was there anything on the angle blocks in the modified structure to take the place of these lugs, or, what became of them?

A. The most of them appeared to have been chipped off.

Q. Was there any thing to prevent the head or foot in these braces from getting out of place?

A. The greater part of the braces seemed to have no provision made for holding them in place.

Q. Did you notice any of these angle blocks where the braces seemed to have changed from their true position, and were sustained merely on the angle blocks?

A. Yes, sir; one angle block showed the braces on one side three inches out of position, and the other as if it was in its true position, and the intermediates in like proportion.

Q. How are you able to tell that this change of position has taken place?

A. The position of each brace is fairly shown in the angle block by the absence of paint, where the brace stood.

Q. This would show, would it not, that the brace was out of position when last painted?

A. Yes, sir.

Q. What proportion of these braces would you think were out of position, more or less?

A. I didn't take the number; there are certainly evidences of these braces being seriously out of place.

Q. Did you examine the top block of the end braces on the west end?

A. Yes.

Q. How did you find that as indicating that the braces were out of place?

A. I can't especially say; it didn't come so much under my notice as those that were in the middle of the bridge, and the one at the other end.

Q. Did you examine other portions of the bridge there, and will you please state what portions of the bridge you did examine?

A. I examined every part, that is, inside, as minutely as I could for the short time I have had there.

Q. Will you please state to the jury, if you have made any observations there, which, in your judgment, were defective in the construction of the bridge?

A. The braces ought to have been so connected together, and adapted to the angle-blocks, that they could not get out of position, either at the top or bottom. These make serious defects, that we can see now. There are other defects which I know of, which don't now show.

Q. You spoke in your former evidence of hearing that the braces, with a small section intended for the centre panel of the truss, were used in the ends; did you find any evidence to-day that satisfied your own mind whether that was true or not?

A. I think nearly all the end braces have been moved from position, but there are several braces of the smaller sections that are cut away very materially, as if they had been made to fit against the largest bolts.

Q. Would that be evidence, to your mind, that they were used in the end panels, where the largest number of braces were required and the largest bolts were used?

A. Yes; because I wouldn't suppose that they would cut away any more metal than was absolutely necessary.

Q. Did you find any evidence, satisfactory to yourself, that the large braces, with inch web, which were intended by you for main braces, had been used as counter braces?

A. There are not sufficient braces in place to enable me to answer that question satisfactorily, but there were some braces near the centre of the bridge that have thick web, not quite an inch thick though.

Q. From what you did observe there, you concluded, did you, that the braces with thick webs were used in the centre of the bridge, and those lighter sections at the end panels of the truss?

A. I can only say that some of the braces which are now near the middle of the bridge have a thick web.

Q. Would this displacement at the head and foot of the braces, both the main and counter, have been likely to attract the attention of the bridge inspector?

A. I think it would be the first thing he would look for.

Q. What would you think of an inspector of a bridge who should fail, for any length of time, in making an inspection of the bridge, to notice the fact of these displacements?

A. A person who was in the habit of reasoning and thinking about strains on a structure, would evidently look at those points the first thing; I should think his observing facilities were not very good if he didn't see them.

Q. By Mr. Perry. I would like to have you state, if you can, where and how the T rails, forming struts between the two lower chords, were placed—at what point in the panel, I mean.

A. The plan shows how they were intended to be placed, and there is evidence that they were in place, where they were intended, when the chords were taken out of the water. You can have the proof, in many places, which can not be seen now, that the struts were in place against those angle-blocks which have a rest on the end side for the lateral bracing.

Q. Can you tell, from your examination this morning, where they were placed?

A. No; but the wrought-iron washer and the first set of bolts don't project on the inside to receive the strut.

Q. From this do you think that they were not placed as they were intended to be?

A. That is my belief.

Q. Were the floor-beams of the bridge intended for struts?

A. They formed the struts to the top chords.

Q. In what manner?

A. They had pieces riveted to them that fit between and against the edges of the beams of the top chord; I think some were between and some against the edges.

Q. Were these pieces intended to go entirely inside of the top chord, or between the members of the chord, by the plan which you drew?

A. Between the members of the chord.

Q. Did you see, in your examination this morning, any of the floor-beams which had these pieces coming between the members of the top chord?

A. I couldn't see; there was only one beam which I would have thought went inside of the chord.

Q. By Mr. Pettibone. Is it in the intention and design and construction of the Howe truss bridge, either in wood or iron, that each and every part of its component parts should bear its proportional share, above the dead weight of the bridge, of the weight which might be placed upon it?

A. Certainly.

Q. Now, what would be the effect upon a bridge, constructed upon the Howe truss plan, wherein its construction and displacement in its principal chord, whereby they didn't get their true bearings and their proportionate weight, originally designed, what would be the effect upon the other parts?

A. The surplus weight would be transferred to other members.

Q. What would be the effect upon those other members, where the surplus weight was carried or conveyed, in relation to their ability to sustain this additional weight?

A. If they were not sufficiently strong they would give way.

Q. If, in your examination of the wreck of the bridge, you found a displacement of any of the component parts of the bridge intended to bear compression, or displacement of any of the members composing these component parts, was it, in your judgment, sufficient to endanger the safety of the bridge?

A. Yes; if one set of braces gave way it was the destruction of that truss.

Q. By Mr. Morrison. What provision was made in the original plan of the bridge for preventing lateral motion, or swaying of the lower chords of the bridge?

A. There was a system of lateral bracing, that commenced at the end of the bridge. The first pair of braces extended one panel, crossing each other in the centre panel. The intermediate lateral bracing extended two panels. The diagonal members of the lateral bracing were tension members.

Q. What was the size of those rods?

A. I didn't measure them to-day, but it is in my mind they were two and one-half by one-half inch flat bar.

Q. Was there a turn buckle in them?

A. I think not. My own impression is that it was the intention to force the struts in very tight, so as to bring them up to tight bearing, driving the struts in sidewise. They had enlarged ends, that fitted in the recess in the under side of the angle blocks, and the angle blocks resting upon the lower chord kept them in place.

Q. In what manner was that enlarged end put into the angle blocks—in the form of a dovetail, or in a sort of a hanging hook?

A. It was formed by doubling over the end bar so as to give about one-half inch to hook the width of the bar.

Q. And there was a recess in the angle block into which that hooked?

A. Yes.

Q. Was there any other provision made for tightening these diagonal tension rods except the one named?

A. I think not.

Q. Was this all the provision made for preventing the lateral swaying of the bridge in this lower chord?

A. Yes. It would be assisted by the vertical tie braces that extended from the upper chord to the lower. The one would assist the other.

Q. In forming the upper chord of this bridge was there the same section of iron used in there to the whole length?

A. It was not the intention. The heavier bars were intended for the centre compression members.

Q. Did you notice the upper chords—you were there to-day—to see whether the central portion of those chords was composed of heavier bars than the ends?

A. Yes. They are.

Q. Is not the compression strain on the middle upper chord?

A. Yes.

Q. Doesn't that require a much larger calculation of material than at the ends?

A. Yes.

Q. The top chord of this bridge resting, as it did, upon the angle blocks, would be subject to a transverse strain in bearing a load upon the bridge?

A. The transverse strain upon those top chords, in my opinion, would very likely affect the strength of them, because they are a continuous beam, and slightly bending upward.

Q. There are, as I understand it, two ways of using the Howe truss, one by using them as a deck bridge, and the other as a through bridge—the load in one case being upon the upper chord, the other upon the lower?

A. Yes.

Q. Which of the two is preferable, so far as securing strength?

A. The deck. The reason for this is, that the load is all on the top, and doesn't have to be carried up, so it makes a panel difference in the length of the bridge.

Q. Is there not a greater tendency to lateral motion in a deck than in a through bridge?

A. I never thought there could be much difference, having never seen any thing to make me think there could be much difference. If there is any, I think a deck bridge would have the advantage, because the vertical diagonal bracing would hold the trusses vertical.

Q. Upon what do you depend upon your vertical diagonal bracing to keep the upper chords steady in this bridge, in particular?

A. When the diagonal rods are screwed up, it would bring the strains on both the upper and lower chords, against the struts that extend from one side to the other, compelling both trusses to retain a vertical position.

Q. In what manner were those vertical tie braces connected at the ends, with the upper and lower chords?

A. They were both connected in the same manner by hooks, with square——fitted into the ends of the angle blocks, and held in place by short screws. The manner in which they were fastened was sufficient to bear any strain that could be brought upon them by the turning buckles.

Q. How often were those vertical tie braces put in?

A. At every other panel, commencing at the end panel.

Q. By Mr. Pettibone: I desire you to state to the jury, and embody it in one answer if possible. What displacement of the different component parts of that bridge have you observed, would in your judgment, endanger the safety of the bridge?

A. Every displacement as far as it goes, is a detriment, and ought not under any circumstances, be allowed to take place.

Q. In relation to these defacements of the beams, or chipping off of part of the beams, what would be the effect?

A. If the beams had been kept in place, so that the bearings were fair on their ends, a chipping off of the corners of the flanges would have been no serious detriment, but when they got out of place, then it become a serious detriment.

Q. By Mr. Morrison: Were you in the employment of Mr. Stone before any thing was said to you about drawing the plan of this bridge?

A. No, sir.

Q. Did he send for you especially to draw this plan, and superintend the erecting of the bridge?

A. I presume so. I do n't know.

Q. Was this the only employment that you ever had from Mr. Stone?

A. Years ago I was with him a short time—about 1847, I think, but did n't see much of him.

Q. Did he send for you at the time when he projected the building of this bridge?

A. Yes. He telegraphed me at Fredington, but how he came to do so, I do n't remember. I know I received a telegram from him and a letter; it was in answer to this telegram that I came to Cleveland.

Q. Did Mr. Stone, at your first interview, inform you for what purpose he had sent for you?

A. Yes, sir. So far as my memory serves, this bridge was the only thing that came up at our first interview.

Q. Did he tell you for what purpose he had sent for you?

A. I could n't tell especially; but this bridge was the only thing before us for some length of time after I did come.

Q. I understood you to say that you were not favorable to the use of the Howe truss bridge for long spans?

A. Yes, sir.

Q. Did you express your objection to the Howe truss bridge at that time for a bridge of this span?

A. I do n't think I did.

Q. How long after you first saw him before you commenced the plan and drawing for the bridge.

A. I suppose right away. There was nothing else for me to do at first. I suppose I commenced the day I came into the office, though I can't remember positively.

Q. Having serious objections to the Howe truss bridge of this length, how came it about that you did n't state those objections to Mr. Stone?

A. Well, I suppose when I first came to Mr. Stone's I looked upon him as a higher authority in bridge matters than myself.

Q. Then Mr. Stone told you just what he wanted done, and how to do it, and you merely drew this plan at his dictation, and in such manner as he directed?

A. Generally, that would be correct; because in carrying out the detail of the plan, there would be, of course, suggestions and consultations between us.

Q. In those conversations did you ever suggest to Mr. Stone that the Howe truss was not the best form of bridge of this span?

A. I think not.

Q. Were you not consulted at all in regard to the plan?

A. No, not in regard to the plan.

Q. You did, then, just what Mr. Stone told you to do, without comment or suggestion?

A. No; I would n't say so altogether. I tried to make a great many suggestions; and I would state here that I do n't consider that the Howe truss can't be made a good bridge, but only it would be so much heavier than any other, and, secondly, more expensive.

Q. Are we to understand from that that the Howe truss bridge, wrought iron, is a more expensive bridge than wrought iron in every other form than a Howe truss?

A. Yes, sir; the saving in material by some other form would be in itself a great saving.

Q. A saving of expense in the erection of this bridge was not then a matter of consideration?

A. I think not. I think it was Mr. Stone's intention to make a first-class bridge.

Q. Did you think at the time that his intentions, as stated by you, were being carried out in the building of this bridge?

A. I don't consider that they were carried out in a perfect manner by any means.

Q. You give us to understand there was no lack of expenditure or any thing to secure a good bridge?

A. I think that generally would be correct.

Q. Can you tell us now why, in your judgment, a good bridge was not secured?

A. The first defect that I would remember was the beams for the compressive members not holding there full section, and also there being defective rolling. I never thought at that time, or since, there was any other defect in the bridge except in those compressive members. In examining the bridge now, I find there are defects, such as not having the braces held securer in place against the angle blocks, these and the end of the braces not being properly secured together and longer length, are what I hold to be the principal defects in the bridge.

Q. You say there were defects in the rolling of the iron; where was this iron rolled?

A. At Newberg.

Q. Was it a part of the business of the Newberg mills to roll "I" beams, and were they prepared to roll them?

A. They had rolled six inch beams, but I don't think they made it a business of rolling beams; there were not many mills in the country at that time that did, because there were not the beams for them; that's been since.

Q. Do you know of their having rolled any I beams at that mill, since that time?

A. No; I have not been acquainted with the mill since then. I always considered that Mr. Jones, the foreman of the mill, understood his business well.

Q. If this was a good mill, and the foreman understood his business, and they were skilled in rolling I beams, how do you account for the defects which you have mentioned?

A. That the mills were not adapted for rolling beams of the largest section.

Q. Do we understand from that, that their machinery for the performance of the work was not adapted—?

A. For the larger beams; that is what I understood at the time. You will observe on the work that the small beams are more perfectly rolled than the large ones.

Q. Do you know who were the owners of this Newberg mill at the time?

A. Stone, Chisholm & Jones, I think were the firm.

Q. Was the Mr. Stone of that firm a relative or connection of Mr. Amasa Stone, or the same individual?

A. I think it was his brother, A. B. Stone, that was in the business.

Q. By Mr. Hall: I think you stated that in your design for the bridge, the expansion rods varied in size, beginning at the abutment, and growing smaller at the center?

A. That is correct.

Q. In your examination of the wreck, did you ascertain whether or not those rods were placed as intended?

A. No, sir; I didn't measure them myself; I only took it for granted that they were not, by the measurement of other persons who were present. I think it is hard to tell positively about that, until they take up more of the lower chords.

Q. You would not, then, be able to state at this time whether they were correctly placed, or not?

A. No, sir.

Q. I understand that what is meant by the factor of safety, is the ratio which the breaking weight of the material bears to the load the bridge is intended to carry. Am I right in that?

A. Yes, sir.

Q. What was that factor or ratio in this bridge, as designed by you, under the directions of Mr. Stone?

A. It is generally presumed that the breaking weight of wrought iron in tension is twenty tons to the square inch; in this case it was loaded with only four tons on the square inch, which made it a factor of safety of five, one-fifth of the breaking weight; assuming that the compressive strain of wrought iron was four tons on the square inch, it would be very much below the crushing strains of iron; the section of iron has to be very materially increased when the member in compression has great length.

Q. You designed this bridge, then, so that the calculation showed that it would bear a load of five beams of what you expected it to carry; was that correct?

A. That was correct in the tension members, but it was not correct in the long compressive members.

Q. How was it in the long compression members, as to the ratio of safety?

A. I can't answer that question positively, because it is a matter of calculation.

Q. Were your compression members according to the standard rules of professional engineering, at that time required?

A. Four tons on the square inch in compression, was a safe starting point, if the columns had been proportional to meet that strain; and the four tons to the square inch in compression would have been safe, if the section had been in proportion to the length, according to the formula of that day.

Q. Taking into consideration the length and position of the compressive members, as designed in that bridge, was the calculation of the compressive members less than the standard rule, or formula, at that time, and if so, about how much less, as near as you can tell?

A. They were much less than any engineer would adopt, if he kept each separate brace as a principal column. If they had been thoroughly united together, then the sections of the bridge, as calculated on the plan, were sufficient—that is, allowing four tons on the square inch.

Q. In your design, was there provision made for so uniting them?

A. No, sir.

Q. Why not?

A. As near as I can remember, the design in my mind for uniting them came up in mind afterwards, because I had not as good sections as it was designed to use in the braces. This was due to the defects in the rolling, in the width, and every thing of that kind; but I don't think that has been the cause of this disaster. I would have used the iron in a different shape. The same section of iron, in a different shape, would have made a wonderful difference.

Q. From what you know of the bridge, from your connection with the designing of it, and from your examination of the wreck since the disaster, are you able to form an opinion as to the bridge falling?

A. I certainly have an opinion, but then the opinion has varied with me as I have got more and more information about it since I came here. But they are only opinions, and are nothing positive. I suppose everybody forms an opinion.

Q. Please state your opinion.

A. In talking with others, and thinking up the matter after I left here, the conviction was very strong upon my mind that the disaster was caused by some one of the sets o the main braces, near the east end, having got out of place, which allowed the structure to fall suddenly; and if that was the cause, that the end braces at the east corner would have slipped off of the angle blocks and struck hard against the masonry, so as to leave an impression. To-day I went up and examined the masonry at all the corners, and at the south corner of the east abutment I found it had been struck by the braces, which confirms my opinion that the disaster was caused by one of the set of main braces getting displaced. That would throw every thing else out of place in an instant.

Q. If lugs had been cast upon the angle blocks, fitting the ends of the braces, as they were originally designed to fit, would it have prevented, or not, the displacement of the braces?

A. Lugs on the angle blocks, fitting against the braces, would unquestionably have kept the braces in place. They could not have got out, unless the brace bolts had been slacked off.

Q. By Mr. Sherman: Before Mr. Stone applied to you to construct this bridge, he was aware that you were an extensive bridge builder, an architect in that department of business, was he not?

A. I couldn't answer for him about that. I don't think that he thought I was very much.

Q. Did he apply to you by letter, or telegram?

A. I think both, sir.

Q. When he wrote to you, did he write to you for what purpose that he desired your assistance?

A. I couldn't say, certain, whether I knew what he required of me before I arrived, or not; but I knew that it was about some bridge that he had to build.

Q. When you arrived in Cleveland, what work did he say he wanted you to do?

A. I think the first thing that was said to me was that he wanted me to plan this Ashtabula bridge.

Q. Did he direct you to plan it?

A. Yes, sir.

Q. Did he direct you to employ your own skill and knowledge in planning it?

A. I can't say that he did, especially, except that it might be skill as a draftsman.

Q. Who designed the bridge, you or Mr. Stone?

A. That would require some explanation. I looked upon the design of the bridge as being a Howe bridge, and the planning of it out in detail is a mechanical operation. I employed draughtsmen all the time in carrying out my own plans.

Q. Who made the design or drawing of this bridge?

A. I did.

Q. Who designed the proportions of the bridge?

A. Mr. Stone.

Q. Do you say that Mr. Stone had any thing to do with the planning and proportioning of that bridge?

A. Yes, sir.

Q. Do you mean to say that the design and proportion of that bridge was made by Mr. Stone alone?

A. Mr. Stone gave me positive instructions to put four tons to the square inch tension and four tons to the square inch compression, and that gave the proportion of the bridge.

Q. Mr. Stone, then, directed you to design a bridge where the compression should be four tons upon the square inch and where the tension should be four tons to the square inch?

A. Yes, sir.

Q. And you designed this bridge to carry out that proportion?

A. Yes, sir.

Q. And in that did you tell him that you had got a factor of safety of five?

A. No. There was no factor of safety talked of at that time.

Q. Well, what did you say to him, if anything, as to the factor of safety on that plan?

A. In answer to this you are aware it is a long time since the conversation took place. I don't think there was any question that came up at all. The rolled beams were delivered, and when I complained about the rolled beams then commenced the trouble between me and Mr. Stone. He wouldn't reason about them or hear about them.

Q. Is that all the answer that you desire to give to the question?

A. Yes. If that is not satisfactory ask me another question. That is all I think I can say.

Q. What did you say to Mr. Stone in regard to these railroad beams?

A. I had finished making a full sized section of the beams that they intended to furnish, and when they were delivered they would not hold to the full patterns. Then I represented to him that was the case. What was said it is impossible for me to say now, but I know this, that he never would allow new rails to be furnished in the place of those that were defective. It is impossible for me to remember the words of the conversation that took place eleven years ago. I can only remember the general impression.

Q. Can you remember any thing that he said to you upon your complaining that the sections were not such as you required?

A. I wouldn't be able to remember any thing of the conversation, but I am positive that he knew that they were defective at the time, and that I was told to mind my own business, or to do as I was told, or something to that effect.

Q. Do you mean to say that you requested Mr. Stone to furnish new sections of different sizes, and that he refused to do so? I would like to have you answer that question directly.

A. It was not my business to request any thing of Mr. Stone. It was only to tell him what was the case. I could only represent the things as they were.

Q. Did you see Mr. Jones, who was the foreman of the shop where these beams were rolled? Did you have any conversation with him?

A. I presume I had, because I had interviews with him on two or three occasions, and became acquainted with him.

Q. Were you there at the time when these beams were rolled, or any portion of them?

A. I am not aware that I was; but I was there after some of them were rolled, but I am not aware that I ever saw any of them rolled.

Q. Did you make any complaints to Mr. Jones, or any of the members of the firm, that these beams were insufficient or defective or would not answer their place in the bridge?

A. No, I don't know that I ever did; because, I don't think that either of them or I would have had any thing to have acted upon, except it was through Mr. Stone's authority.

Q. How often did you see Mr. Collins, the chief engineer of the road, during the time of the construction of the bridge?

A. Almost every time he was in the office when I was at the office.

Q. Did you make any complaints to Mr. Collins, or any other officer of the company, that Mr. Collins was furnishing you with beams that were defective or insufficient for that bridge?

A. I have no doubt it was talked about in Mr. Collins's presence; that Mr. Collins had nothing to do with it.

Q. Do you now swear, that you intimated any thing of the kind to Mr. Collins, at any time before this disaster?

A. I have no doubt that Mr. Collins know that I was very decided that the materials that were going to be used in those braces were insufficient; I am sure that I spoke about it frequently in the office.

Q. You mean, then, to be understood that from information derived from you, Mr. Collins knew that the material or construction of those beams were insufficient for that bridge?

A. Mr. Collins knew that they were defective—that is my belief.

Q. Do you think that Mr. Collins, knowing that there were defective compressive members in that bridge, would have permitted it to have been used for the traffic of the road?

A. I don't know what Mr. Collins's mind may have been about it, but I know this much,-that Mr. Collins was not going to interfere with Mr. Stone; if it had been his business, then it would have been different, but he had no business with it; never allowed to interfere with the works in any shape or form; and I think when Mr. Stone took a large thing of that kind he would trust to Mr. Stone's judgment.

Q. Even if he knew he was building a man-trap?

A. It isn't exactly fair to say that it was a man-trap; a thing may be very defective and yet there are means of making it secure.

Q. Do you say that Mr. Stone, in the construction of that bridge, did not rely upon your skill and experience in bridge-making alone for its safety?

A. He certainly didn't. If he had he would have heard what I had to say.

Q. Have you had any correspondence with Mr. Stone since you left that work, and since the construction of the bridge, in relation to it?

A. Not a word.

Q. Did you state to any of the officers of the road other than what you stated to Mr. Collins, that would be an unsafe bridge if it was completed, or so intimate to any person?

A. No; I don't think I did.

Q. When Mr. Stone consulted with you in regard to the construction of the bridge on your first arrival in Cleveland, did he then state to you that he desired to build a bridge—first-class—for safety, without regard to expense?

A. I don't remember any such conversation; but still I have no doubt he did, and moreover I have no doubt that he thought it was so.

Q. Did you think, when you made the drawing for the bridge, that the main braces, as they appeared in your drawing, and the manner of their being coupled together, would be sufficient for the purpose?

A. I considered that the sections of four tons to the square inch of compression in those braces was safe, as far as carrying the load was concerned. But I didn't consider there was any thing like the strength in them that there was in other parts of the structure.

Q. Did you consider them sufficient for safety?

A. Yes.

Q. In your drawing there is no provision of strength, other than by the coupling, that is pointed out on that drawing?

A. Yes; that is so.

Q. And at the time you made that drawing you also made strain sheets and furnished it to Mr. Stone, in which you represented to him that the bridge was safe, and that there was a factor of safety of about five?

A. No. I made a strain sheet that showed the section. No, sir; that showed four tons to the square inch in tension, and four tons to the square inch in compression, as I was told, had.

Q. And did you think that was safe and secure—a safe bridge?

A. It would, in my opinion, been a safe bridge, but not proportioned properly, so as to have been as strong as it might have been made, by proportioning it differently.

Q. Did I understand that the tension members of the bridge, in your judgment, were fully sufficient?

A. Yes, sir.

Q. And that the only compression members of the bridge, you think, that were defective or insufficient were the set of braces at the end of the bridge?

A. The top chords of the bridge were insufficient in their members, in so far as they were defective in the width of their webs.

Q. Did you make any complaint at the time to Mr. Stone of the construction of the bridge, that there was any insufficient members of the top chord?

A. Certainly I did. There is no question about it. He knew it as well as I did.

Q. It isn't your opinion, however, that the bridge fell from any insufficiency of these beams?

A. No, sir.

Q. Did you say Mr. Tomlinson that when the set of braces at the ends, were strengthened by adding two more in the third panel and one in each of the others, that the bridge would be rendered sufficiently strong in that respect?

A. I believe I have said so because the additional beams would make them about equal, and what was intended in the first place.

Q. How many angle block on the south truss did you examine, to ascertain whether the braces bore upon as they ought to have done?

A. There are only—I think only three inside, and they don't show of displacement in the braces that those do that are on the other side.

Q. How much displacement did you discover in those angle blocks or braces, on the south side?

A. Sufficient displacement for the whole width of the flange to be off from the angle blocks, which would be probably about three-quarters of an inch.

Q. How much would that weaken the members or braces that were thus displaced, in your judgment?

A. It wouldn't seriously weaken it.

Q. Do you know whether there was any displacement of the brace in the first panel of the bridge at the east end.

A. That is the one that is ¾ of an inch displacement; I believe it has that displacement.

Q. Are you able to determine that that was the angle block at the east end, from the examination which you have made?

A. I wouldn't like to swear to it, but I believe it to be so. I had hoped to go down this afternoon and make an examination and take measurements; my view this morning was very hasty, and the timbers that had fallen down, prevented me from making a close observation, as I wished to have done.

Q. Could you determine, if you would make a critical examination, as to where this block was, whether in the east end or not?

A. Yes, sir, if it is the same as it was this afternoon.

Q. The lateral and the vertical bracing was all correct; all right as far as you were able to examine?

A. The vertical braces, I have no doubt, were in their proper places; so also was the lateral tie braces; but the struts were not at the foot of the vertical braces, and at the meeting of the horizontal tie braces, so I believe there is every evidence of it.

Q. The reason that you are able to determine that the braces were displaced was, from the paint, or absence of paint.

A. The absence of paint showed where the braces had been when last painted; most of them.

Q. Could you tell as to whether last painted, or the first time, when they were painted; whether there had been any movement or displacement of the braces since the bridge was painted the first time?

A. I can't tell how they were when it was painted the first time, but I should consider that there is positive proof that they were out of place when they were last painted I might say, seriously out of place.

Q. Is there any circumstance about this place, of the blocks or braces, that enables you to swear positively?

A. That they have ever moved since the bridge was first erected—I can't certainly swear how they placed the braces when the bridge was first erected. But it is impossible to believe that any one should erect a bridge with braces with such imperfect bearings against the angle blocks.

Q. Suppose that bridge, when it was completed for business, was at the time tested by six locomotives rolling over it at the same time, and every thing stood firm, without any unusual deflection one way or the other of the bridge, what would you say as to what it was, in your opinion—whether it was a safe bridge or not?

A. As far as the deficiency in section was concerned, with defective iron, it might have been a secure bridge, and yet be so defective in detail that it would be only a matter of time when the braces would be so much out of place as to let the structure fall.

Q. Under that test, if the compressive members of the bridge were insufficient in sections, would you not expect to find some evidence of it?

A. Members of the structure may be very deficient in the quality of the material and the size of the sections, and yet carry, without any apparent yielding, cars loaded in a large traffic.

Q. Would not the test that I have suggested be a fair one for the bridge?

A. Should be fair, of course, on those compressive members.

Q. And when such a bridge, after that test, has stood and borne the traffic for a period of eleven years, without giving any evidence of failure, does it not furnish strong evidence as to strength and safety of the bridge in its construction?

A. It undoubtedly furnishes evidence that the bridge has sufficient strength to bear the wear and tear that it has had, but doesn't furnish that evidence that the long compressive members were equal to the strong tension of the members of the bridge.

Q. Do you know any thing as to the quality of iron that you used in this bridge?

A. I always believed, and still believe, that the material that was in the brace bolts and the bottom chords were very good, and so, also, was the workmanship; and anybody can look at the beams, that they are not what they ought to be.

Q. Do you mean in the quality of the iron, or in their manufacture?

A. The quality of the iron, of course, I can't speak of; but it isn't in the quality of the iron, but it is in the deficiency of the flanges. They are ragged edges, with deep indentations in them, which weakened them.

Q. Those deficiencies can now be seen or examined, I suppose?

A. Yes.

Q. If those brace beams, when the bridge was first set up, deflected from the weight of the bridge, and when that weight was removed they went back to their original position, would they not be fit to use in the bridge?

A. I would consider them fit to be used—that is, if they had not been compressed so as not to be shorter than the original length that was required. I consider them fit to use, if of sufficient strength to prevent them from deflecting the second time.

Q. There would be no difficulty in a mechanic who should put up the bridge to discover any such defect, I suppose; he would naturally discover it, would he not?

A. I should think he would discover it. Any one who understood the nature of iron would naturally measure it to see if it held its length.

Q. Did you call the attention of any body to examine the east abutment where you think you discovered that the set of braces which fell struck against it?

A. There were two gentlemen upon the bridge at the same time when we examined the stone work. One of them gave me his card with the name of Albert H. Howland, C. E., Boston. The name of the other I do n't know.

Q. What was the character of those indentations, if you can describe them?

A. The appearance would be as if some thing had struck back against the stone, and made a scrape upward, making a pretty deep indentation.

Q. Did you, while in Cleveland last, state to Mr. Collins, or to any of the officers of the company, that the only defect that you could discover or knew of in the bridge was insufficient brace members at the end of the bridge, and if the original plan or design of the bridge had been so altered, with two more braces included in the original plan, and the bridge was thus put up, then you would be satisfied; that the bridge then was, in substance, safe, without any defects known to you?

A. No; I never stated that in full, as you state.

Q. What effect, in your judgment, would be made upon that bridge by a car or engine pulling, after it got on the bridge, moving at 10 or 15 miles per hour on such a night, with such temperature as they said at the time of this disaster?

A. If the bridge had been strong throughout its tension members, it would have little or no effect upon it. The ties were placed so near together, and there were such good guide rails, that the wheels would run from tie to tie, jarring the bridge, but certainly not injuring it.

Q. What effect upon the iron of that bridge would the variations of the temperature have, if any?

A. The variations of the temperature—low temperature would shorten the bridge so that the ends that were on the rails would throw off—so that the difference between extreme warm weather and the extreme cold would be about one and a half inches. I have been in the habit of calculating the changes that do take place in structures on account of these changes, which is a matter of calculation entirely.

Q. In a sudden shock would extreme cold weaken the bridge, in your judgment?

A. Where a sudden shock comes on cold short iron I have no doubt it will snap much