JOURNAL

OF THE

ASSOCIATION OF ENGINEERING SOCIETIES.

Boston, St. Louis, Chicago, Cleveland, Minneapolis, St. Paul.

TRANSACTIONS

Of the Boston Society of Civil Engineers, the Engineers' Club of St. Louis, the Western Society of Engineers, the Civil Engineers' Club of Cleveland, the Engineers' Club of Minnesota, and the Civil Engineers' Society of St. Paul.

VOLUME V.

November, 1885, to October, 1886.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES,

16 & 18 CHAMBERS ST., NEW YORK.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. July, 1886. No. 9.

THE SEVENTH STREET IMPROVEMENT ARCHES.

BY W. A. TRUESDELL, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read October 5, 1885.]

When the Seventh street improvement was commenced in the spring of 1883, it had been decided to make the Phalen Creek crossing an earth embankment, and the work in its details was to be done on that general plan. This embankment was to be 66 feet wide on the top, the full width of the street, and 640 feet long, from bluff to bluff. The greatest depth in the valley was 86 feet below grade. The filling up of this valley would require a culvert 320 feet long for Phalen Creek and a stone arch bridge at the crossing of the St. Paul & Duluth Railroad. A description of the last structure as it was built, and a history of its construction, is the object of this paper.

The right of way of the Duluth road was 70 feet in width, and the angle of intersection with Seventh street was 63° 28″. For this reason an oblique or skew bridge would be required, with an obliquity as near to the above angle as possible. The vertical distance from the railroad track to the grade of the street above was not sufficient to span the right of way with one arch, as sewer, water pipes, etc., would have to be built eventually above the arch. After conferring with the authorities of the St. Paul & Duluth R. R. Co., it was decided to cover the 70 feet with two arches, one of 27 feet and the other 37 feet direct span, reserving about 6 feet for a centre pier. This gave track room for five tracks, two passenger tracks through the small arch, and three for freight traffic through the larger arch.

On this agreement, plans were prepared and specifications drawn up during the months of June and July, 1883, and on the 27th of August following the contract for building the whole structure was awarded to Mr. M. O'Brien, contractor, of St. Paul. Before the work had been commenced, this contract was modified by resolution of the City Council, and with Mr. O'Brien's consent, so as to include only that part of the structure up to the springing lines of the arches. The remainder of the work was to be included with the other work of the Seventh street improvement, the contract for which was soon to be let.

In designing these arches, it was an earnest endeavor to keep the cost as low as possible, and, at the same time, a substantial structure was required. It was a question of great importance at this time what method of building an oblique arch to adopt. Every known method of constructing such a bridge was duly considered. Nothing of the kind had ever been built in this western country. Very few of our masons in St. Paul had ever seen one, and no one knew anything about the stone-cutting necessary. All of them would consider it an expensive undertaking. At most it was entering on an untried field of operations.

The ribbed arch plan was first considered, and then rejected. Such a structure would have been unstable for this locality on account of the great weight of earth the arches would have to sustain. The stones of one rib could not be bonded into those of the next rib. In such arches it is often necessary to insert iron tie-rods along the crown to hold the ribs together. Nothing, probably, would have been saved in the stone-cutting.

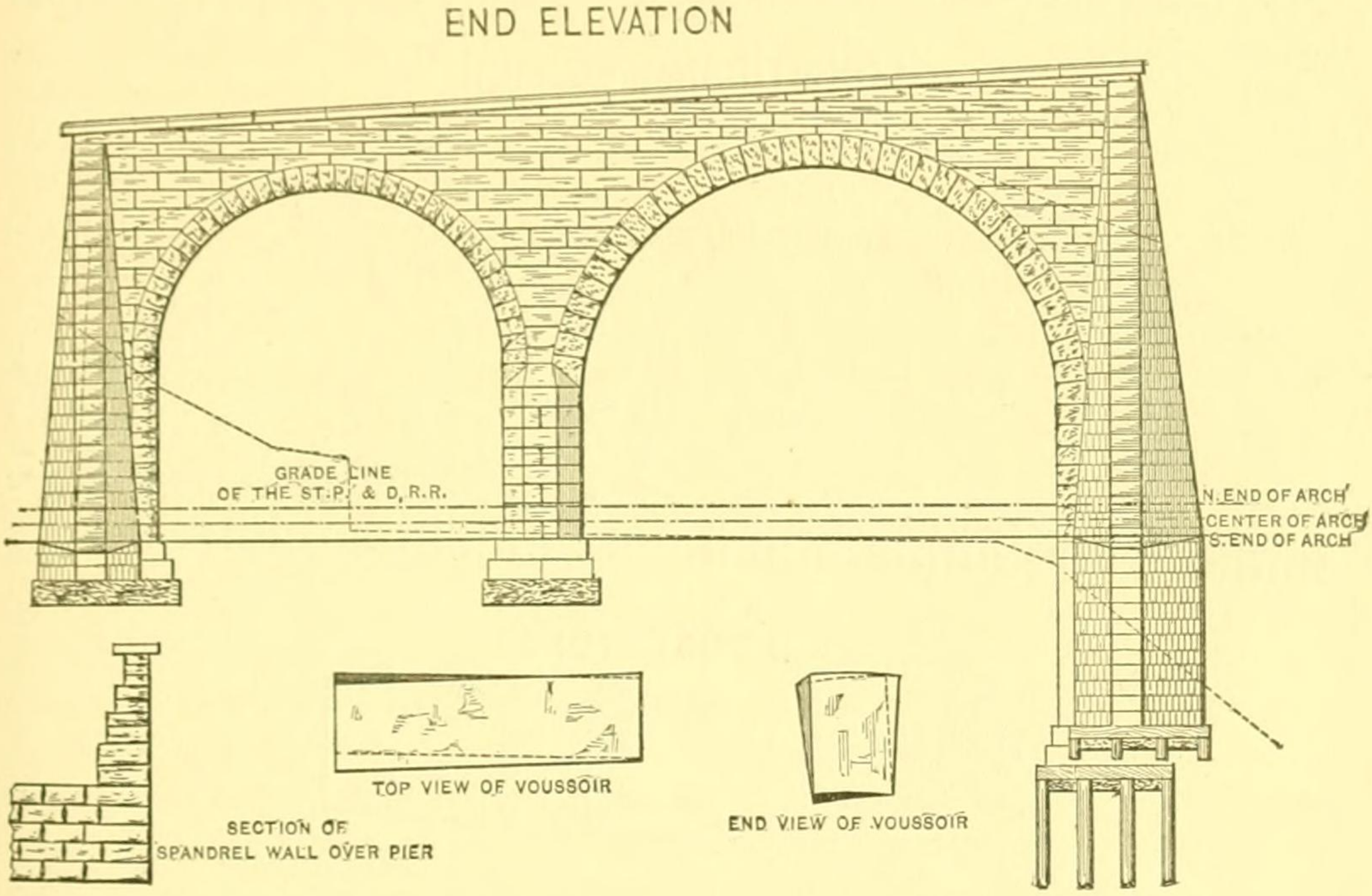
The logarithmic method, or perhaps what had better be called the French method, is the strongest oblique arch that could be built. The joints near the ends of the arch are nearly parallel to the springing line. But the voussoirs of such an arch could never have been cut in this locality. It would have required a great number of patterns and the cost of such a work would have been beyond all consideration. This method was too expensive and impracticable to be adopted.

It was finally decided to adopt the helicoidal method, or the English style of an oblique arch, as it appeared to be the least difficult and expensive to construct of any of the known methods. These are quite common in England and Scotland, but very few have ever been built in this country. In this style of an oblique arch the voussoirs are laid in spiral courses, parallel with each other, and are of one size and shape throughout the whole arch except the ring stones. One set of patterns answers for all of the voussoirs, and when the stone-cutters are once taught to cut a stone no further difficulty is encountered.

The theory of the helicoidal method is this: The beds of the voussoirs, or rather the bed of any one course, is a helicoid or a warped surface, generated by a straight line which intersects the axis of the arch, and is continually at right angles with it, and which moves uniformly along that axis and at the same time revolves uniformly around it. The intersection of any one of these warped surfaces with the soffit of the arch is a curve known in mathematics as the helix, and is called in practice a coursing joint. The joints which separate the stone in a course from each other are called "heading joints," and are portions of warped helicoids. On the soffit of the arch they are at right angles to the coursing joints. The soffit of the voussoir is, therefore, a rectangle, but this is not true on the extrados of a voussoir. There the angles vary considerably from right angles. A right section of such an arch must always be circular, either semi-circular or segmental. But the arch is really elliptical, because the beds of the stones are approximately at right angles with the line of thrust, which would act parallel or nearly so to the face of the arch.

This was the method adopted for the Duluth viaduct, and both arches

were planned on that principle. These plans were for two arches, one for 27 feet and the other for 37 feet, direct span. The angles of obliquity were 63° 49 and 63° 40′. Oblique spans were 30 feet and 1 inch, and 41 feet and 3½ inches. Each arch was to be 124 feet and 7 inches in length, both of them full centre arches, the springing line of the small one 3 feet and 4 inches above that of the larger one. The arch rings were 2 feet and 2 feet 4 inches deep. The east abutment was 7 feet and 3 inches thick at the springing line, the centre pier 6 feet, and the west abutment 6 feet and 1 inch, the total width of structure 83 feet and 4 inches. The spandrel backing was raised 10 feet above the springing line of the small arch and 13 feet and 6 inches over that of the large one. Wing walls were to be built on each end of the east and west abutments. These varied



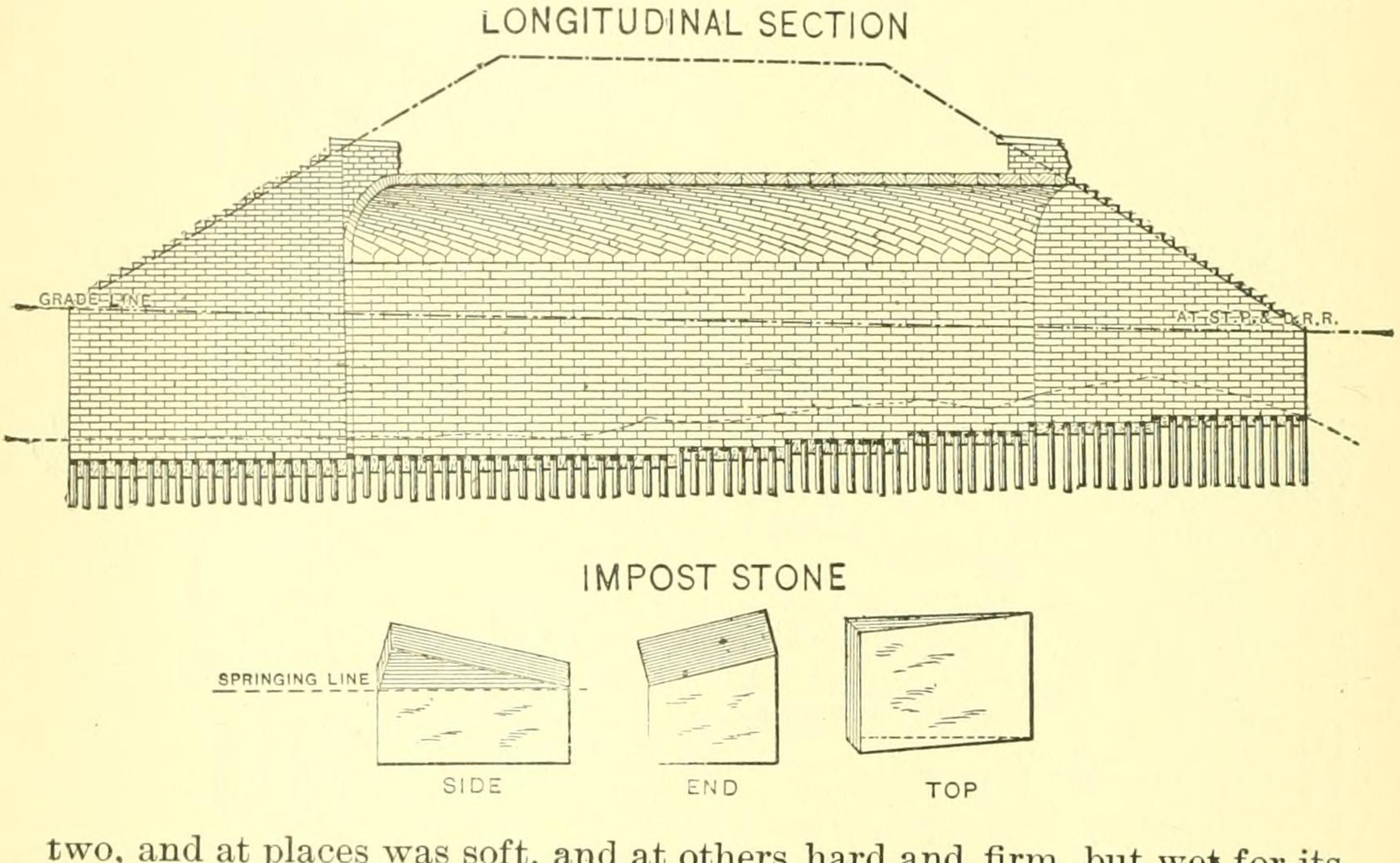
from 47 feet to 58 feet in length and from 30 feet to 37 feet in height above the grade of the railroad. The parapet walls were to be each 96 feet long and carried up 4 feet above the crown of each arch. The height of parapet walls above track is 36 feet. The coping stone surmounting the parapet wall was laid parallel with the street grade above, which was 4 feet and 10 inches per one hundred feet. The springing lines were horizontal, but the railroad tracks descend through the arches at a grade of 2 feet per one hundred. The viaduct was subsequently built according to these plans, with slight alterations made as the work progressed.

On September 6, the old Seventh street trestle was closed to travel, five bents of it removed, and the excavation for the east abutment commenced. Pile-driving for the foundation commenced September 27, and was completed on November 3. On the 10th of November, the contractor commenced laying stone, and the work continued during the winter, with interruptions at different times on account of cold weather, until the following spring, when the east abutment, with its two wing walls, was completed up to the springing line on April 20. Meanwhile, the excavation of the west abutment had been made and the laying of stone

commenced April 9, and was completed, with the two wing walls, early in May. Two railroad tracks at that time occupied the present position of the centre pier; one of them was removed, and the other thrown over near to the west abutment. The pit for the centre pier was then excavated, the sheet piling driven on each side to prevent sliding of the material, and on May 24 the masonry was commenced and completed on June 6. This finished the work under Mr. O'Brien's contract.

The west abutment and centre pier were built directly on earth foundations of a firm gravel and sand, with wide footing courses. Each foundation is 5 feet below the present grade of the railroad tracks at the south end, and 7½ feet at the north end. This depth was considered below the action of frost.

The foundation of the east abutment was about 18 feet below the other



two, and at places was soft, and at others hard and firm, but wet for its whole length. The masonry of this abutment was built directly on piles.

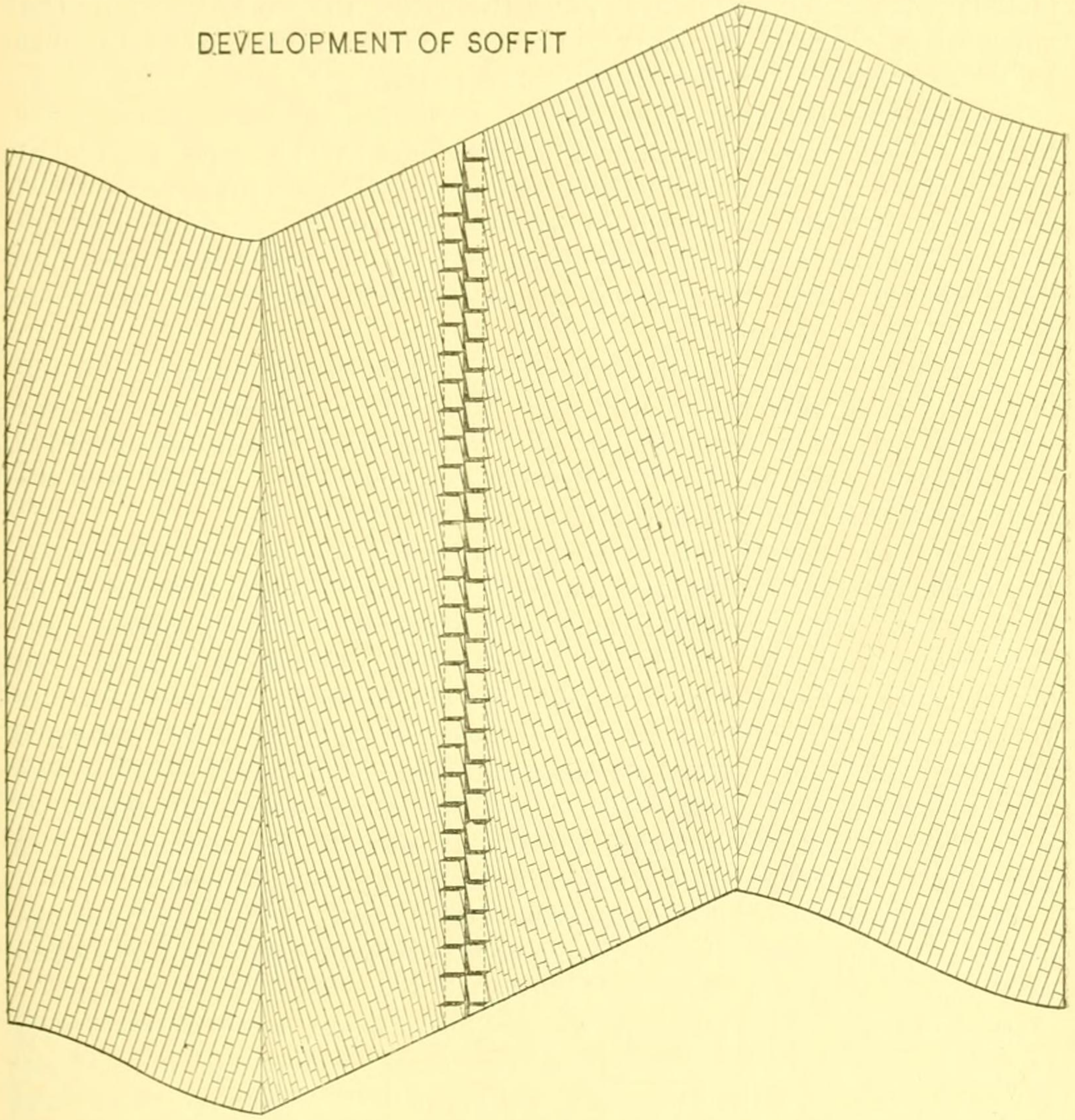
The whole work so far was built of St. Paul limestone. Louisville cement mostly was used in the mortar. The masonry was very heavy. Most of the courses were 16 inches and 18 inches thick, some of them 20 inches and 22 inches thick. No course less than 12 inches thick was allowed. The back of each abutment was built as substantial as the front, and no stone was laid in any course of less depth than the thickness of that course.

The centre pier was built after the Flemish style of masonry. Each header extends through the wall and is underlaid and overlaid by two stretchers, the width of the two stretchers being equal to the thickness of the wall. Each stretcher abuts at each end against a through header. Very little filling was allowed.

Throughout the whole work the contractor did everything in a substantial manner. The total amount of masonry in Mr. O'Brien's contract was 3,567 cubic yards, including the concrete.

Drawings of the patterns for stone-cutting had been made the previous winter, and the patterns, or most of them, made by the American Manufacturing Company, at their shops in St. Paul. These templates and bevels were 105 in number, and were made of iron, wood, zinc and paper. Those that were to be used continuously were made very solid of iron and wood. Those used once or twice only were of paper. Duplicates of those used the most were afterwards made, so that from 25 to 30 workmen could be kept at work continuously in the quarry.

The only difficulty met with in cutting the voussoirs and impost stones



was at the commencement of the work, and was in making the stone-cutters understand the importance of accurate and careful work with the patterns instead of the ordinary work to which they had been accustomed. This was overcome by placing an intelligent and trustworthy foremen in charge of all stone-cutters, and from that time afterwards all work was done in a first-class manner. To Mr. Thomas Russell, the foremen in charge at Mankato, great credit is due for the successful manner in which he performed his work. Every stone was accurately tested with a set of templates and bevels made for that purpose exclusively before it was shipped to St. Paul.

The McArthur Brothers, of Chicago, under their contract for the improvement of Seventh street, continued the work from where Mr. O'Brien left it, and in July commenced laying the impost stones. After these were laid for both arches three courses of voussoirs were laid on the centre pier, two on the east side, and one on the west, and the backing put in between them in order to obtain room for two derricks, with which the whole work could be reached. The centring for the small arch was then put up and the voussoirs laid as rapidly as possible, while the centring for the large arch was placed in position. This was completed on the 12th of September, and thereafter the work of laying the voussoirs was carried on over each arch, simultaneously, until October 14, when the last one was laid in the large arch.

The spandrel backing was carried up at first with the voussoirs over each abutment and centre pier. The remainder of the stone work was then hurried to completion. The backing was completed, the wing walls and spandrel walls built, both arches were plastered over with concrete three inches thick, and the coping stone laid. A dry wall three feet thick was then built back of each spandrel wall to relieve the spandrels from the earth pressure.

The masonry of the viaduct was completed on the 25th day of November. A trestle was then built over both arches, dump cars run over from the adjacent embankment, and the Phalen Creek fill extended over the whole work. The first teams passed over the viaduct and the entire Seventh street fill, on the 18th day of December.

That part of the work built by McArthur Brothers, except the wing walls, was constructed of Mankato stone, from the Empire stone ledge of W. D. Craig & Co. Utica cement was used until cold weather, when Louisville was substituted. The arch stones were laid in mortar composed of one measure of Utica cement mixed with one of sand. There were 1,764 voussoirs and impost stones in both arches, and all of these were quarried and cut in Mr. Craig's Mankato quarry in three months' time. This fact speaks well for the capacity of that quarry. Only about one-fourth of the stone quarried was suitable for these voussoirs, the remainder was used in other parts of the work and in the Trout Brook masonry.

There is in voussoir and impost stones 1,122 cubic yards of masonry. In the whole work there are 3,474 cubic yards of Mankato stone. The spandrel backing contains 1,026 cubic yards.

Oblique arches are often built of hard burnt brick, with the ends only of cut stone, and, of course, at much less cost. It was not deemed expedient to construct the Seventh street arches in this manner, on account of the great weight of earth with which they were to be loaded. Something enduring and substantial was required. The extra cost of stone over brick was money judiciously expended.

It is probably the general opinion of the public that these arches have been an expensive undertaking. On account of the apparent difficulty of cutting the stone, the idea prevails that to build arches of this kind must necessarily require a greater outlay of expense than if they were right arches. I wish to contradict this idea. With the contractors of the Seventh street work, the stone-cutting was neither difficult nor expensive. The Seventh street improvement embraced quite a number of

different classes of work in given quantities, and the whole improvement was performed for a stated price. For this reason, the exact cost of the viaduct alone to the city is not easily obtained. Whatever information I possess on this subject is the property of the contractors and cannot be mentioned here. I wish merely to state that any excessive cost in the Seventh street arches does not exist. This probably could not be done again, but is true in this instance. The two arches have cost no more than two right arches would have done for the same locality.

During the progress of the work the traffic on the St. Paul and Duluth Railroad was not in any way obstructed. The centring was raised, all the voussoirs laid, and, in fact, the whole work constructed with trains and switch engines continually passing and repassing under the arches.

Each centre was built " cocket," as there was a track through each arch. The ribs were made entirely of two-inch plank, and were 5 feet 4 inches apart in the small arch, and 4 feet in the large one. The ribs were supported by plates 6 inches by 12 inches, extending along the springing lines, and these, in turn, supported by vertical posts 8 inches by 10 inches reaching to the footings of the masonry. The ribs were put together close at hand and raised to their position with the derricks. They were placed at right angles to the axes of the arches. There was consumed in these centres over 135,000 feet B. M. of timber. They were designed by Mr. Jas. McArthur, one of the contractors. During the progress of laying the voussoirs, not the slightest settlement in either was noticeable. The lagging was 3 inches by 6 inches, timbers 16 feet long, thoroughly spiked to the ribs and planed on the upper surface. On this lagging the coursing joints were all marked from the impost of one side over the lagging to the other impost. It would have been impossible to have laid the voussoirs without this precaution. On these lines strips one-half inch by two inches were nailed, and on these strips the coursing joints were again drawn. The faces of both arches were also drawn across the lagging. These lines were guides for the masons in bedding the stones, care being taken to make the joints always correspond with the line. The voussoirs were not laid by courses, but in horizontal rows from one end of the arch to the other, both sides brought up at the same time ; when the last row of keystones was put in, it fitted to its place and was grouted with mortar made very rich with cement.

The total amount of work done under the two contracts is as follows :

Earth excavation	7,172	cub. yds.
Piling	3,487	lin. ft.
Concrete	168	cub. yds.
Masonry in east abutment	1,222	" "
Masonry in west abutment	588	" "
Masonry in centre pier	586	" "
Masonry in wing walls	1,437	" "
Masonry in arches	1,122	" "
Masonry in spandrel backing	1,026	" "
Masonry in spandrel walls	326	" "
Plastering on arches	635	sq. "

Total amount of masonry in the whole structure, 6,528 cubic yards.

There are, in the smaller arch, 62 impost stones and 754 voussiors. These voussoirs are all of the same size, except the ring stones, and are 5 feet 8½ inches in length, and 2 feet deep, and contain 14.8 cubic feet. Each one weighs 1.15 tons. The large arch has 48 impost stones and 900

voussoirs. The voussoirs are of different lengths near the springing lines, after which they are all of the same size, 4 feet 11 inches long and 2 feet 4 inches deep. Each one weighs one and a half tons. All voussoirs and impost stones are bush hammered on the soffit. The embankment over each arch is 18 feet deep. The greatest pressure on any part of the work is at the skew-backs of the large arch, where it is 170 pounds per square inch.

After the whole work was completed, the centres were allowed to aremin in place during all of the past winter until May, when both of them were struck and the timbers removed. Each rib was loosened so easily that it seemed to indicate that the arches had been to a great extent supporting themselves. This was probably due to the shrinkage of the timber during the six months that it had remained in place.

It is advocated by some, that centres should be struck as soon as the stone work over them is completed. The experience with these arches appears to prove the contrary, and that the safest plan is to keep them in place as long as possible.

ANNUAL ADDRESS.

By J. F. Holloway, President Civil Engineers' Club of Cleveland.

[Delivered March 13, 1886.]

I shall occupy the time at my disposal in attempting to say something about the "Engineer and what he has accomplished."

I find myself at the beginning embarrassed by the difficulty of giving a satisfactory definition of the term, engineer, even the name of our association is to some extent a misnomer. While its title is the "Civil Engineers' Club," its constitution gives as the object of its organization "the encouragement of social intercourse among men of practical science and the advancement of engineering in its *several* branches," and it also provides that its "members shall consist of persons who are or have been engaged as civil, mechanical or mining engineers, architects, astronomers, geologists or analytical chemists and other persons engaged in scientific pursuits." Comprehensive as is this list of persons who are eligible to its membership, it by no means includes all of the recognized branches of engineering or of engineers. If, years ago, when engineering was far less comprehensive in its scope, when it was confined within comparatively close limits, it puzzled the ablest lexicographers to clearly define its meaning, how much more difficult must it be to do so now, since the engineer has invaded so many pursuits which hitherto got on very well without him.

That there were engineers long ages ago is testified to by the ruined structures still to be seen; structures for whose formation there was need of carefully prepared plans and carefully constructed appliances. Three thousand years before the Christian era began, in that wonderland of the past, Egypt, engineers planned and built an artificial reservoir which, for vastness, has never yet been equaled. For its protection there was built a wall of masonry 40 feet high, 30 feet wide and 27 miles long; within it

JOURNAL

OF THE

Association of Engineering Societies.

ST. LOUIS. BOSTON. ST. PAUL. MONTANA.
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MILWAUKEE. UTAH.

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VOLUME XLII.

January to June, 1909.

PUBLISHED MONTHLY BY

FRED. BROOKS, SECRETARY OF THE BOARD OF MANAGERS OF THE
ASSOCIATION OF ENGINEERING SOCIETIES.

31 MILK STREET, BOSTON.

It was the good fortune of the junior member of your committee to be intimately associated with him for sixteen years as assistant, partner and friend, and in all that time he never heard a single unkind word or an impatient expression pass the lips of Mr. Harris. Passion seemed to have no part in the makeup of Mr. Harris, but his sympathy was broad as heaven, and his constancy to duty could not have been greater. His influence upon the community in which he chose to labor during nearly forty years was not small, even if it was marked by no spectacular achievement. The men who have made this country great are the thousands who, each in his own community, have stood for truth and honor and charity and faith. Of such was Isaac K. Harris.

He died May 21, 1906, after about a year of lingering illness.

Otis F. Clapp,
Edwin F. Dwelley,
Committee.

William Albert Truesdell.

Honorary Member Civil Engineers' Society of St. Paul.

Died April 21, 1909.

William Albert Truesdell was born in New York City March 25, 1845. He was the fourth son of Verdine Truesdell, a steamboat owner and captain on the Hudson River, and Elizabeth Knapp. In 1851 the family moved to Wisconsin and finally settled on a farm at Wautoma.

After a high school course at Berlin he entered, at the age of eighteen, the University of Wisconsin, where he supplemented the general course by a special study of engineering, graduating in 1867. Then followed rather lean times for the young engineer. For a few winters he taught school. For a dozen years he was engaged off and on, here and there, principally in land and railroad surveying. He had then established a reputation as a locating engineer.

He married Miss Malvina N. Baker December 5, 1879. One son and two daughters survive him, Mrs. Truesdell having died about four years before his decease. In 1880 he entered the service of the St. Paul, Minneapolis & Manitoba Railway Company, and a considerable part of his work, probably a total of twenty years' service, on reconnoissance, location and con-

struction, has been for that corporation and its successor, the Great Northern Railway Company. All lines of construction, road bed, masonry and buildings received his attention.

While connected with the St. Paul City Engineers' Department in 1883–84, he designed and superintended the construction of the most important piece of masonry in the city, the twin skew arches which support Seventh Street over the St. Paul & Duluth Railroad. These arches, 124 ft. long, span 27 ft. and 37 ft.

His charge of the foundation of the Columbia River Bridge, built by the Great Northern Railway Company in 1895, sustained his reputation as an expert in this line of work. The construction of the general offices of the Northern Pacific Railway Company in 1896–97, and the erection of the Great Northern shops in St. Paul in 1902–03, were subject to his inspection. In 1897–98 he had charge of the Union Stock Yard Company's improvements in South St. Paul.

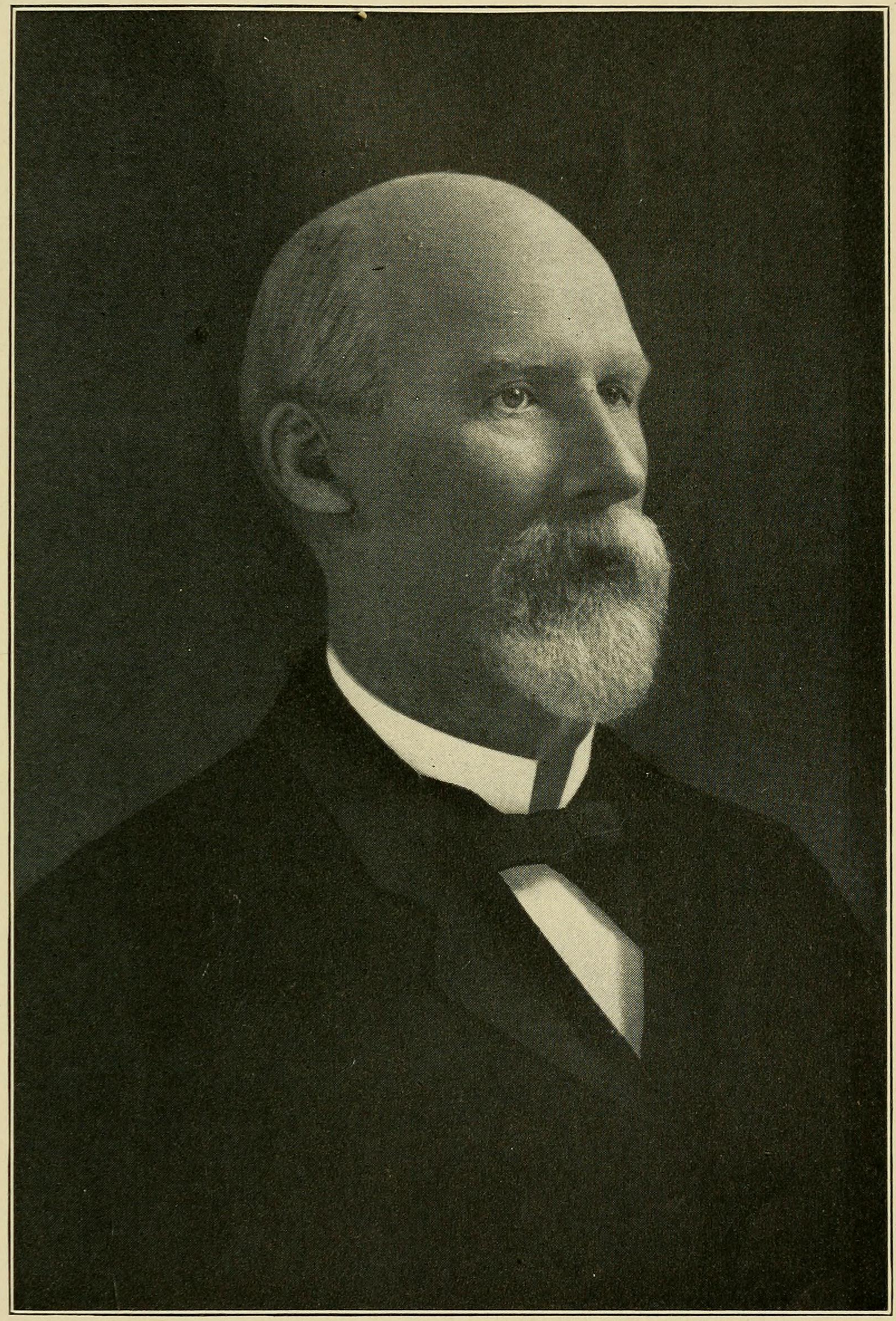
He does not appear to have been affiliated with many societies. The Hesperian Society, of Madison, Wis., was an early venture.

As a charter member of the Civil Engineers' Society of St. Paul, he contributed much to its success, in recognition of which he was advanced to honorary membership November 18, 1905. The following record tabulated from minutes of society meetings shows his continued interest in affairs of the society. The list gives subjects treated and dates of presentation:

"Building Materials," June 14, 1884; "Building Stone of Minnesota," April 6, 1885; "The Seventh Street Improvement Arches," October 5, 1885; "The First Engineer," March 4, 1895; "Work at the Union Stock Yards," February 7, 1899; "Life of Archibald Johnson," January 15, 1904; "Origin of System of United States Land Surveys," March 14, 1904; "The Rectangular System of Surveying," October 12, 1908.

Most of the above papers were published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The *Wisconsin Engineer* published his paper on "Foundations" in October, 1896.

His recreation was in the study and investigation of such subjects as the history of the Constitution of the United States, the development of the science of mathematics, early western explorations, etc. His researches resulted in the getting of much information of special and lasting interest, which had long been hidden in volumes of matter of minor or temporary importance.



This he compiled in a complete and orderly manner. For fifteen years he delved for the substance of the paper on rectangular surveying.

His maps of the route to Astoria by the pioneers of 1810, together with explanatory manuscript notes, now repose in the library of the Minnesota Historical Society. There, too, were placed copies of his map and notes illustrating the Birch Coulie and Wood Lake affairs of the Sioux uprising in 1862.

The desire to go to the beginning of things and to clearly trace the development from first principles of subjects with which he was brought into contact led him to search among much dry matter for those pertinent facts which appear in his historical papers. It will be noted that it was his general practice to record the results of his experience and the outcome of his researches for the information of his associates.

Before going to the scene of his last assignment, in May, 1908, he attended a regular meeting of the Society bearing two valuable old books, the gems of his collection. In reminiscent mood he presented them to the Society. The evening was his. Such was the farewell, probably unanticipated. The following October he was forced to leave his work at Judith Gap, Mont., suffering from the effects of the high altitude, which induced an affection of the heart. He returned to his home in Minneapolis. In December he began to realize that the malady was serious, but he remained hopeful of recovery until almost the end, four months later.

His reputation for practical sense, thoroughness and accuracy was exceptional. Handicapped for many years by deafness, aggravated by exposure and advancing years, this bluff, undiplomatic, outspoken man of rigid standards seldom smiled, and yet he had a kindly manner, revealing a character which commanded respect, admiration and affection.

C. L. Annan,
A. H. Hogeland,
Alfred Jackson,
D. F. Jürgensen,
Committee.