Utah. These are for portions of the distributing system from Carson River.

Bids were to be opened on June 15 for the controlling works at the outlet of Lake Tahoe at the head of Truckee River.

NEW MEXICO.—The Hondo Dam and canals have been nearly completed under contracts awarded to the Slinkard Construction Co., of Roswell, N. M., and the Taylor-Moore Construction Co., of Hillsboro, Texas.

NORTH DAKCTA.—The Fort Buford Canal contract was awarded from bids opened June 5, 1905.

SOUTH DAKOTA.—The Belle Fourche Canal is being built under contracts let in May, 1905, to S. R. H. Robinson, St. Louis, Mo., and The Widell-Finley Co., of Mankato, Minn.

WYOMING.—Bids will be advertised at an early date for work in connection with the storage works and canal on the Shoshone River.

In the states not mentioned above active operations have been carried on and every effort is being made toward early construction. There have been, as was expected, many engineering difficulties; but the largest source of delay has been in acquiring necessary rights or titles. The Government in its acquisition of property is required by law to be extremely cautious and can not assume risks, as in the case of individuals. The preliminary matters leading up to the purchase are examined by suitable legal experts connected with the Reclamation Service, several of these being men who have had engineering education and experience and have later taken up the study of law and been admitted to the bar. This training has been invaluable in adding to their effectiveness in this particular line of work.

The duties of the Reclamation Service are not merely those of surveying and construction, but enter into all matters of policy in dealing with individuals and communities. It is necessary not merely to build great hydraulic works for storing and distributing water; but more than this, the land must be subdivided into tracts or farm units capable of sustaining a family and the people must be organized, so that the works may be paid for by the canal owners in ten annual instalments. When thus paid for they are turned over to the operation and control of the community. This necessitates dealing with a large number of individuals and the gradual creation of a system which is in many respects similar to the municipal ownership of public utilities.

Moreover, not only must there be a tactful dealing with people, but consideration must be given to the capabilities of the soil and to the dangers of its becoming reduced in value by seepage or percolation of waters and by the development of alkali. These matters of alkali and of drainage are studied with other engineering features and experts are designated to give their entire time and attention to the laying out of the irrigation system, with its related drainage works, to prevent future disaster.

In brief, it may be said that in the space of three years an organization has been devised and put in successful operation to cope with the engineering and physical difficulties and to deal with people and problems scattered throughout the western half of the United States. The future development and prosperity of many communities is dependent upon the wise conduct of this work, for the creation of thousands of homes in the arid and semi-arid parts of the United States means not merely the prosperity of these localities, but the stimulation of all industries throughout the country. The farmers on irrigated lands are, when firmly established, the largest producers on limited areas. They practice the most intensive cultivation, raising two, three or more crops each year. These communities offer the best home markets and the transportation and manufacturing interests of the country find in them their strongest support.

It is therefore not to be wondered at that President Roosevelt, with his broad knowledge of the whole country, has given much personal thought to irrigation and has put the strength of his personality behind the passage of the law and into its successful execution. The actual operations are in the hands of Secretary Hitchcock, and he in turn has delegated the details to Director Walcott. Too much can not be said in praise of the latter's executive ability and the sound judgment in handling the many problems presented to him. Mr. Walcott while not a professional engineer has built and brought to successful termination many large enterprises, and has rendered most effective services to the Government of over a quarter of a century. All of this has been done in addition to his scientific investigations and conduct of a great bureau.

A NOTABLE REDUCTION OF TYPHOID FEVER IN CHICAGO, 1881 TO 1904,* INCLUSIVE.

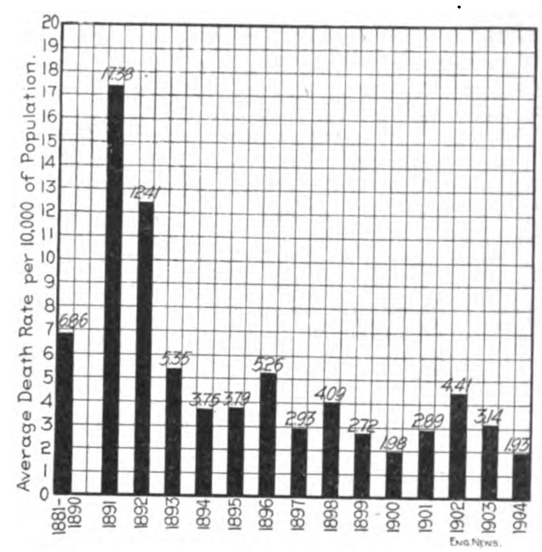
Chicago's finally successful fight against typhoid fever covers a period of less than a dozen years.

In 1891 it had the highest typhoid death rate of any large city in the world—17.38 per 10,000 of its population.

In 1905 its typhoid rate is among the lowest—1.21 per 10,000 for the 147 elapsed days of the year, and a reduction of more than 93% from the rate of 1891.

The 1891 rate had a single obvious cause—a sanitary blunder. The 1905 rate is the result of persistent, intelligent sanitary effort.

Typhoid fever began to increase materially with an increase in the number of lake-emptying sewers. At the



Reduction of Typhoid Fever in Chicago Death Rates per 10,000 Population, 1881 to 1904, Inclusive.

close of 1888 there were but three sewers discharging into the lake—those at Twelfth, Twenty-second and Thirty-first streets. Subsequently these were increased to 11 south of the main river and to 18 north of Fullerton Ave.

At the time when this monstrous sanitary crime was committed the city's water supply was taken from the lake at distances varying from 1,400 ft. to two miles from shore. With the increase sewage in the shore water typhoid increased, so that the 375 and the 453 typhoid deaths of 1888 and 1889, respectively, were swollen to 1,008 in 1890, to 1,997 in 1891, and to 1,849 in 1892.

The success of the World's Fair was threatened. Chicago was advertised to the uttermost ends of the earth as a plague-stricken city, to be shunned by all who valued health and life. Herculean efforts were made to remedy the conditions; tunnels were extended; shore intakes were abandoned; the completion of the Four-mile tunnel was hastened, and the sewage-pumping works at Bridgeport were pushed to the limit.

As a result the total typhoid deaths during 1893, the World's Fair year, fell from a yearly average of 1,498, immediately following the multiplication of the lake-emptying sewers, to 670—a decrease of more than one-half (55%).

Since that time there have been further tunnel extentions and a new two-and-a-half-mile tunnel—the Carter H. Harrison—has been constructed, so that at present all intakes are beyond the zone of sewage pollution under usual conditions.

Supplementing this work, in order of priority, came the diversion of the Twelfth St. and the Twenty-second St. sewers from the lake to the South branch—recommended to the Mayor in a communication from the Department, dated Oct. 9, 1897. This diversion was completed in the autumn of 1898 and was followed in 1899 by a 60% improvement in the sanitary quality of the Four-mile tunnel supply—the supply chiefly affected by the discharge of these sewers.

Next, the August, 1899, Bulletin announced that "After three years' effort the Department has succeeded in prohibiting the deposit of river and harbor dredgings in Lake Michigan within eight miles of the shore line—except within the inclosed space known as the Lake Front Basin." This prohibition was secured only after repeated demonstrations of pollution of the Four-mile tunnel supply by these deposits, even after the sewers' diversion.

At midnight Jan. 17-18, 1900, the Drainage Channel of the Sanitary District was put in operation, and during the last year the South Side intercepting-sewer system was concluded from the lake south of Fullerton Ave.

The appended diagram and table are from the forthcoming report of the Department for the year 1904. Together with the foregoing summary, from the same source, they are commended to the study of the author of a recent magazine article on typhoid fever in Chicago, every line of which betrays the fine enthusiasm of youth and the courage of its ignorance.

*From the Bulletin of the Health Department of Chicago for the week ending May 27, 1905; Arthur R. Reynolds, M. D., Commissioner of Health.

TYPHOID FEVER MORTALITY IN CHICAGO, 1881-1904, INCLUSIVE.

Years	Population Estimated for the intercensal years by U. S. Census Office.*	Deaths from typhoid fever.	Death rates per 10,000 of Population.	Ratio per cent. of typhoid to total deaths, all causes.
1881	540,000	568	10.51	4.09
1882	560,693	462	8.25	3.49
1883	580,000	361	6.22	3.12
1884	629,885	354	5.61	2.84
1885	665,000	496	7.45	3.98
1886	703,715	483	6.86	3.53
1887	760,000	382	5.02	2.48
1888	802,651	375	4.67	2.35
1889	935,000	453	4.84	2.67
1890	1,099,850	1,008	9.17	4.60
1891	1,148,795	1,997	17.38	7.20
1892	1,199,730	1,489	12.41	5.67
1893	1,253,022	670	5.35	2.47
1894	1,308,682	491	3.75	2.05
1895	1,366,813	518	3.79	2.14
1896	1,427,527	751	5.26	3.24
1897	1,490,937	437	2.93	2.00
1898	1,557,164	636	4.09	2.70
1899	1,626,333	442	2.72	1.73
1900	1,698,575	337	1.98	1.34
1901	1,757,010	509	2.89	2.09
1902	1,815,445	801	4.41	3.63
1903	1,873,880	585	3.14	2.07
1904	1,932,315	373	1.93	1.42

(*Estimates for intercensal years are made on the arithmetic basis, or by adding for each one-tenth the increase during the ten years between the two last censuses. By this means some of the yearly rates per 10,000 population differ from figures previously published by the Chicago authorities, based on school attendance, police censuses, and names in city directories.—Ed.)

THE NEW WESTMINSTER BRIDGE OVER THE FRASER RIVER, BRITISH COLUMBIA.

Substructure.

One of the notable bridges recently built on Canadian soil is the double-deck railway and highway structure crossing the Fraser River at New Westminster, British Columbia. This bridge is shown in diagram elevation by Fig. 1. The total length of the main steel structure is 1,780 ft., divided into eight spans of the following lengths, counting from the north end: 225-ft., 380-ft., 380-ft. and five 159-ft. spans. The 225-ft. span is of novel construction, in being 136 ft. wide at one end and 19 ft. wide at the other end, and the second 380-ft. span is a swing span. All the other spans are fixed spans. The superstructure described is carried on piers of stone masonry. It provides for highway traffic on its upper deck, and its lower deck carries a single line of railway track, which at Pier III. branches right and left on 12½° curves, necessitating the peculiar form of span noted above, which has been dubbed a spread span by the engineers. This span, the erection of the bridge by floating the spans into place, and the foundations, which are among the deepest in the world, are the more notable features of the work. The bridge was built for the Department of Lands and Works, Province of British Columbia, by Waddell & Hedrick, of Kansas City, Mo., as engineers, and by Armstrong, Morrison & Balfour and the Dominion Bridge Co. as contractors. Mr. Harry K. Seltzer was the Res. Engr. in charge of the work. It was completed and opened for traffic on Oct. 1, 1904.

CHARACTERISTICS OF SITE.—The site of the bridge is 15 miles from the point where the Fraser River enters the Strait of Georgia. At this point the river at the water line is 2,100 ft., and as there is a tide difference of from 3 ft. to 7 ft. in 24 hours, its waters have two currents each way during most of the year. Under ordinary conditions these currents have a velocity of

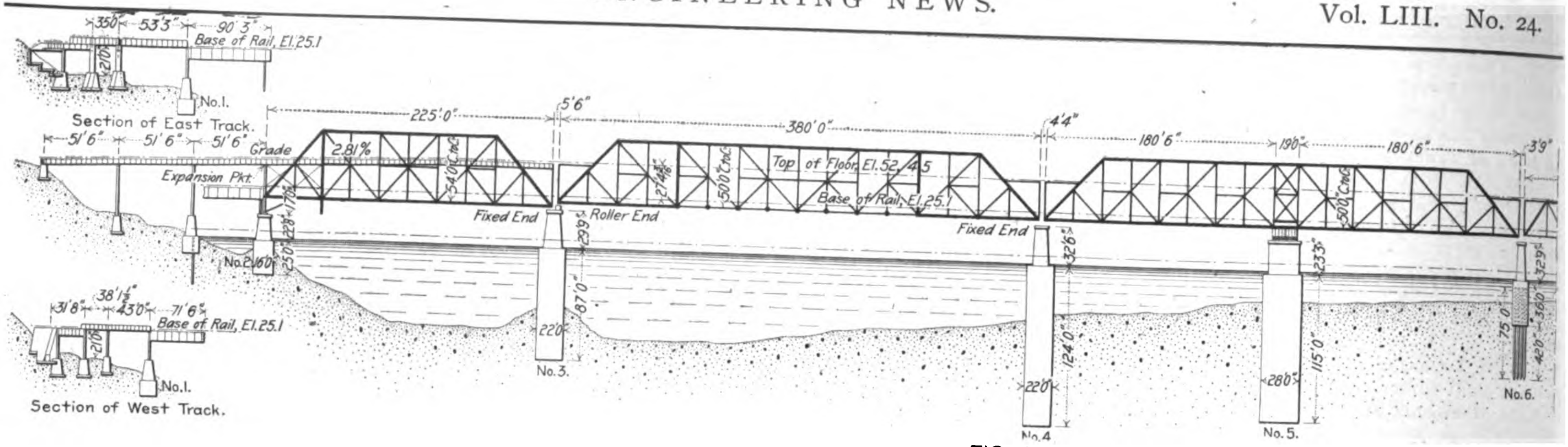


FIG. 1. DIAGRAM ELEVATION OF BRIDGE ACROSS THE

from 2½ to 3½ miles per hour, but during the Spring freshets a velocity of 7 miles per hour has been observed. As indicated by Fig. 1 the north bank of the river is high and the bed of the river from this side drops off rapidly to a point between Piers III. and IV., where there is from 80 to 85 ft. of water at ordinary stages of the river. And this far the river bed consists of a very coarse gravel, interspersed with large boulders, and covered with some 20 ft. of fine silt, containing logs. The remaining portion of the river bed to the south consists of silt, through which occur layers of fine sand, clay and fine gravel.

GENERAL DESCRIPTION.—The substructure consists of 17 piers, 11 pedestals and 3 abutments. All the pedestals and the two abutments on the north shore are concrete. The main pier shafts are of granite masonry backed with concrete. The concrete used for the pedestals and north shore abutments is a 1-3-5 broken stone mixture, faced with 1½ ins. of 1 cement and 2 sand mortar. The pier foundations are of two kinds; Piers I. to V., inclusive, are open caisson or crib foundations, and Piers VI. to XI., inclusive, are pile crib foundations. The cribs in all the pier foundations were filled with concrete of 1 cement, 2 sand and 3 ¾-in. broken stone. The pier shafts are coursed ashlar.

ABUTMENTS AND PEDESTALS.—The concrete abutments and pedestals call for mention only in respect to the forms used. These consisted of 2 × 6-in. dressed and matched lagging boards, supported by a rigid timber frame. The facing was applied by blocking steel plates 1½ ins. from the frame, filling behind these plates with concrete and between them and the lagging with 1-2 mortar, and then withdrawing the plates and tamping the mortar and the concrete together to a close bond. The surface finish secured by these means was remarkably perfect.

PIERS I. AND II.—The foundation denoted as Pier I. consists of three pairs of piers, which carry the steel columns of the one highway and two railway approaches. Each of the six piers consists of a crib 16 × 16 ft., 13 ft. high, surmounted by a concrete shaft 16 ft. high. They were constructed by building cofferdams and sinking the cribs by excavation in the dry with pick and shovel.

Pier II. supports the wide end of the spread spans and consists of two shafts and cribs spaced 136 ft. 6 ins. apart. Each crib is 16 ft. square and 25 ft. high, and carries a masonry shaft 24 ft. high and 10 ft. square under the coping. It was planned to sink these cribs by open dredging inside, but the steep slope of the river bed and the fact that it consisted of cemented gravel filled with large boulders made it impossible to accomplish the task in this manner. A shelf or bench was, therefore, dredged for each crib by cutting down the high side of the bank from 10 to 15 ft. The cribs were seated on the prepared benches and then filled with concrete in the usual manner; their bottoms were protected by riprap.

PIERS III., IV. AND V.—Piers III., IV. and V. are all located in deep water, and consist of masonry shafts founded on timber cribs and caissons sunk by open excavation through central wells. All three cribs were of similar construction, but differed in dimensions and shape. Those for Piers III. and IV. were rectangular and had the following dimensions:

	Pier III.	Pier IV.
Lateral dimensions of crib..........	22 × 40 ft.	22 × 37 ft.
Height of crib...............	87 ft.	124 ft.
Wells in crib (two)...............	8 × 8 ft.	8 × 8 ft.

The crib for Pier V. was an octagon, 28 ft. in diameter, with a central well 12 ft. square, and was 115 ft. high. The shaft for this pier is a cylinder 24 ft. in diameter and 23 ft. 6 ins. high. The shafts for Piers III. and IV. have the following dimensions: Pier III., base, 35 ft. 4 ins. × 13 ft.

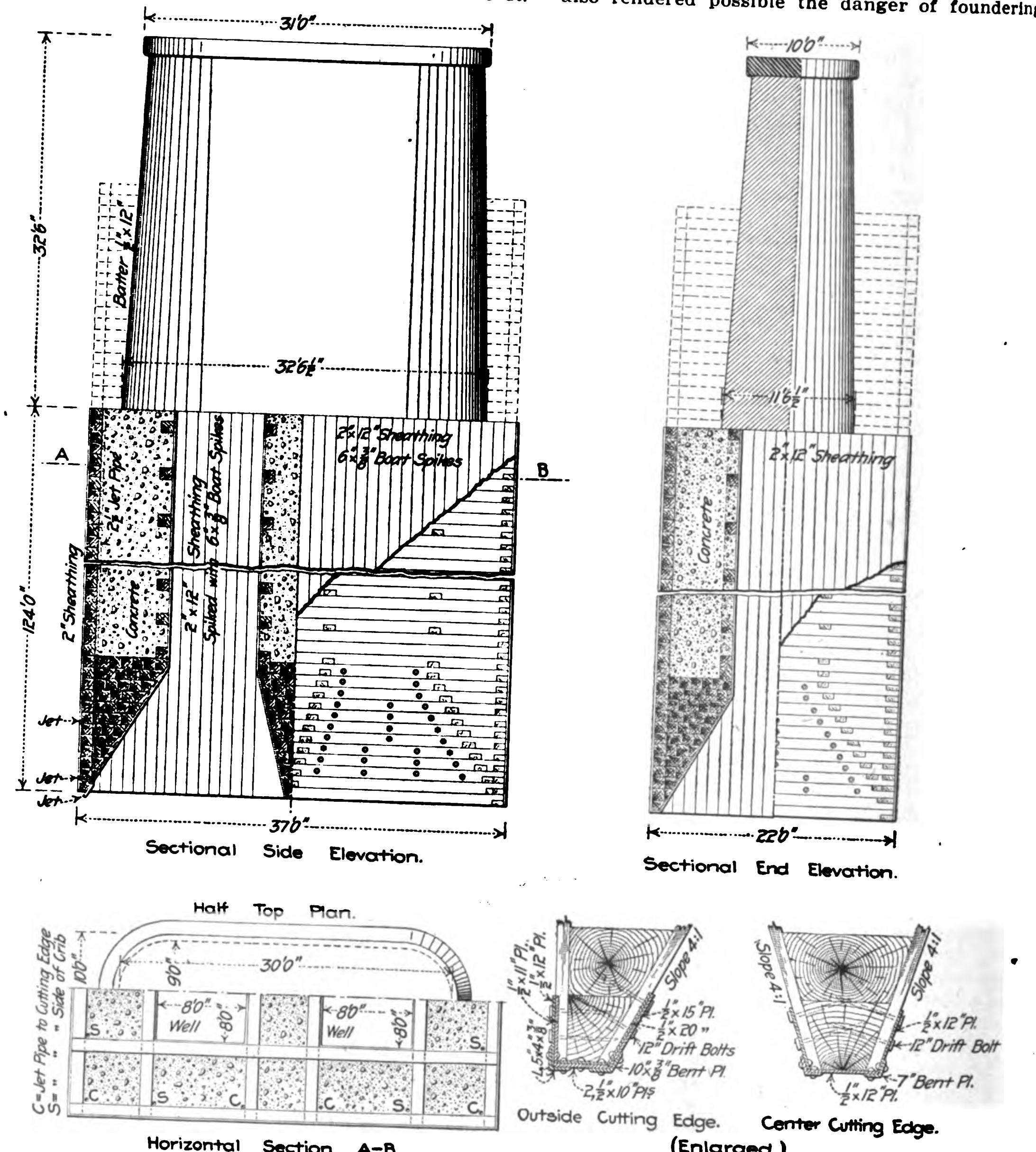


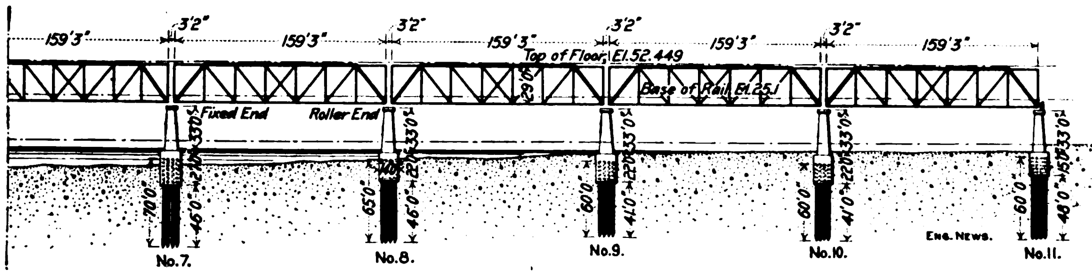
FIG. 2. DETAILS OF TIMBER CRIB FOR PIER IV., FRASER RIVER BRIDGE.

10 ins.; height, 27 ft. 9 ins.; Pier IV., base, 11 ft. 6¾ ins. × 32 ft. 6¾ ins.; height, 32 ft. 9 ins.

The construction of the cribs in detail is fairly well indicated by Fig. 2, which gives the drawings for Pier IV. The cribs for Piers III., II. and I, were substantially the same in form and construction, but differed, of course, in dimensions. The octagonal crib had the same solid exterior walls and solid timber cutting edges. In case of these deep-water cribs it was important that the walls should be perfectly water-tight, since any leakage into the dry compartments prevented the dry filling with concrete that was desired, and also rendered possible the danger of foundering

It was found to be a simple matter to make the walls tight by caulking the joints from the outside with oakum. To secure tightness in the decks was a more difficult matter. The pressure of the water here was upward, and, as the caulking had to be done from the top, it forced the oakum out of the joints. This difficulty was successfully overcome by caulking the two topmost courses of deck timbers and then filling all joints flush with hot pitch. Generally, all cribs were constructed complete to a height of 14 ft.

before launching, and when afloat their decks were about 3 ft. above the water surface. Directly after launching the bottoms of the dry



FRASER RIVER, AT NEW WESTMINSTER, B. C.

compartments were sealed with an 8-in. layer of 1-2-3 concrete, which was allowed to set several days before sinking was begun.

The usual methods of open-caisson work were pursued in sinking the foundation cribs; excavation was carried on from the surface through the central well and the crib was forced downward by filling the dry compartments with concrete. To hold the cribs in position during the sinking process, they were moored between guide piles within pile docks, whose upstream faces consisted of piles driven close to form a V-shaped breakwater. These docks formed the supports of working platforms. The crib for Pier IV. was landed on the bottom in 50 ft. of water, but during its sinking this depth was increased to 65 ft. by scour. The final depth reached by the bottom of the crib was 135 ft. below ordinary water level. Excavation was stopped in a bed of fine gravel, at a penetration of 70 ft. The crib for Pier V. was sunk to a depth of 125 ft. and landed in a bed of clay and gravel, with a penetration of 90 ft. The original depth of water was 35 ft., but this was increased to 50 ft. by scour. The basins formed around the cribs of Piers IV. and V. by scour were filled with riprap.

The crib for Pier III. was sunk in 80 ft. of water and has a penetration of 45 ft. It is founded in a bed of course gravel and boulders, overlying which there is 20 ft. of fine sand and silt. Owing to the sloping surface of the hard material and the presence of logs in the overlying silt, this crib gave more trouble than any of the others. When the crib landed on the bottom the concrete in the chambers was 35 ft. below water level. The filling was gradually carried up as the penetration increased, but owing to the great height of the crib and to the soft material it was found advisable not to bring the concrete nearer than 15 ft. to the water surface. After sinking 10 ft. into the soft material the crib landed on several logs on its north side, and later again landed on the hard material, which was 18 ins. higher on the north side than it was on the south side. Both of these circumstances caused the crib to lean badly; its total height at the time was 102.5 ft., and it was 4 ft. out of plumb. As any agitation due to excavation in the wells only caused the crib to lean further, the condition was rather serious.

An examination showed that the logs were of considerable size and sound; one of these ran completely across the caisson and was 2 ft. in diameter. It was decided to remove these obstructions by blasting. An augur with a 3-in. bit and a shank 100 ft. long was constructed; its point was set by a diver and it was turned from the top. After boring a number of holes through the log a charge of dynamite was placed in each and exploded. The logs being removed, the crib was loaded on the high side with concrete and stone, and a dredge was set at work taking away the material on the outside of the north cutting edge. This was a tedious task of several weeks' duration, because the soft material overlying the gravel ran so that a large basin had to be excavated. As soon, however, as the dredge began to take away the coarse material the crib began to right itself and gradually came to a vertical position. Riprap was deposited around the base of the crib to fill the basin formed by dredging and scour.

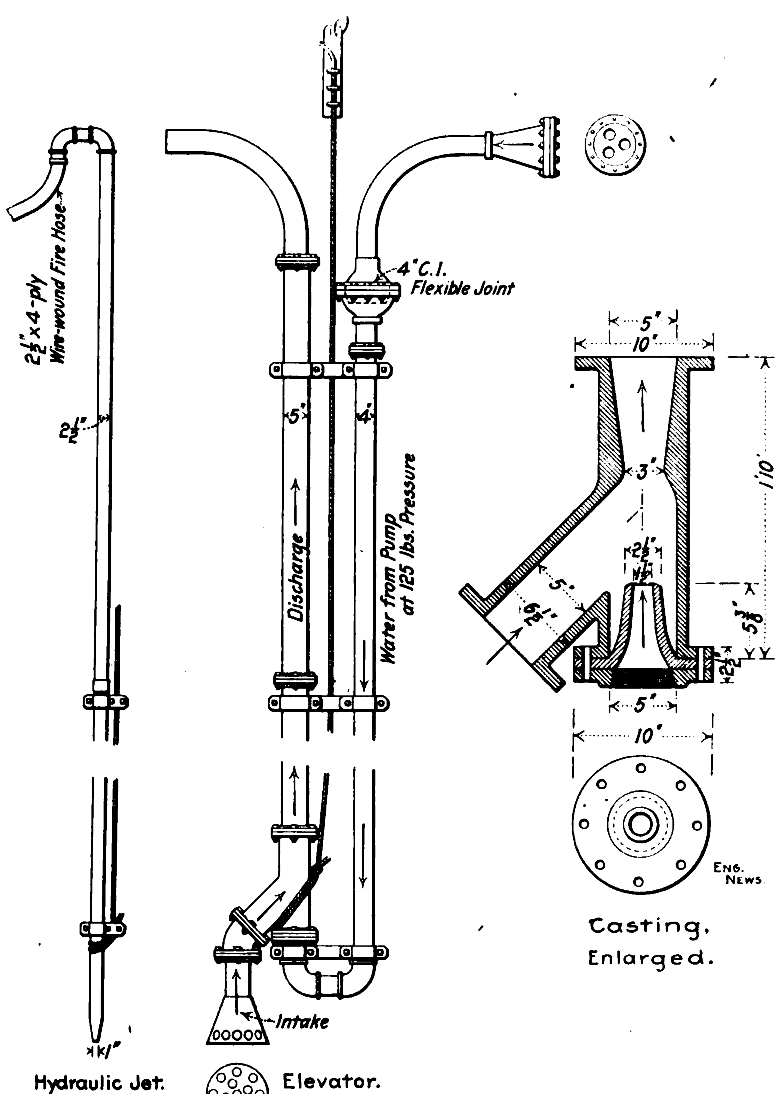


FIG. 3. DETAILS OF EJECTOR FOR EXCAVATING INSIDE OF FOUNDATION CRIBS.

The sinking of the cribs for Piers IV. and V. was straightforward work. All but about 5% of the excavation was done with an ejector or hydraulic elevator of the construction shown by Fig. 3. This device could handle material of any size up to 2½ ins., the diameter of the throat, and was found to be quite as effective at great depths as at smaller depths. The jet shown in the drawing, in connection with the ejector, was used as an agitator; when placed near the suction it greatly increased the efficiency of the work. When coarse gravel or other material was encountered which the elevator could not handle, the apparatus was lifted clear of the bottom and placed in one corner of the well, and a clam-shell dredge was operated for a short time. It was found that the ejector had a decided advantage over the dredge in the point of maintaining the cribs in position. With it, by placing the suction close to the side of the well, the material could be drawn from the high side or the point that was holding up, and by placing an extension on the intake, material could be drawn from directly under the cutting edge. The rate of sinking depended greatly on the material encountered; it varied from 2 to 6 ft. in 24 hours.

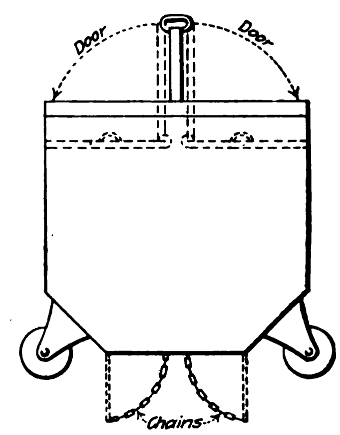


Fig. 4. Bucket for Depositing Concrete Under Water.

The concreting of the cribs comprised two operations; first, the filling of the outside compartments, and, second, the concreting of the central well. In the cribs for Piers IV. and V., as soon as a small amount of penetration had been gained, the concrete in the side compartments was brought above water level and all but the 2-in. sheeting was omitted about the wells. In crib III., owing to the difficulties previously mentioned, it was never possible to bring the concrete to the level of the water surface, and it was, therefore, necessary to continue the solid well timbers to the full height of the crib. The concreting of the wells was done through water until the filling had reached a height at which the well could conveniently be pumped out. In crib V., 75 ft., and in Piers III. and IV., 55 ft. and 65 ft., respectively, were concreted dry. As soon as the wells were laid dry the sheeting between them and the side compartments was torn out so that the inside and outside concrete would have all possible chance to bond. The concrete was deposited through water by means of the special bucket shown by Fig. 4.

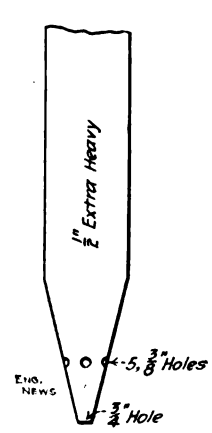


Fig. 5. Sketch of "Rose" Jet for Driving Foundation Piles.

PIERS VI. TO XI.—The six piers carrying the five 159-ft. spans, as shown by Fig. 1, are founded on pile cribs. Each crib, with the exception of No. XI., which is an end pier and contains 21 piles, has 32 piles arranged in four rows of eight piles each. These piles were driven by a hydraulic jet of the pattern shown by the sketch Fig. 5, and known as a rose jet. These jets were developed as a result of unsatisfactory experience with the ordinary single vent jets, which always stuck fast after the pile had been driven, and had to be loosened by sending down a third jet. The rose jets solved this difficulty, and they also showed greater ability to loosen and penetrate the gravel. Two of them were used on each pile. They were operated with a water pressure of from 150 to 200 lbs., supplied by a Worthington duplex pump with 20 × 12-in. × 14-in. stroke cylinders, 9-in. suction and 7-in. discharge, taking steam at 100 lbs. pressure from two 50-HP. locomotive boilers. The same power plant was used to operate the ejectors.

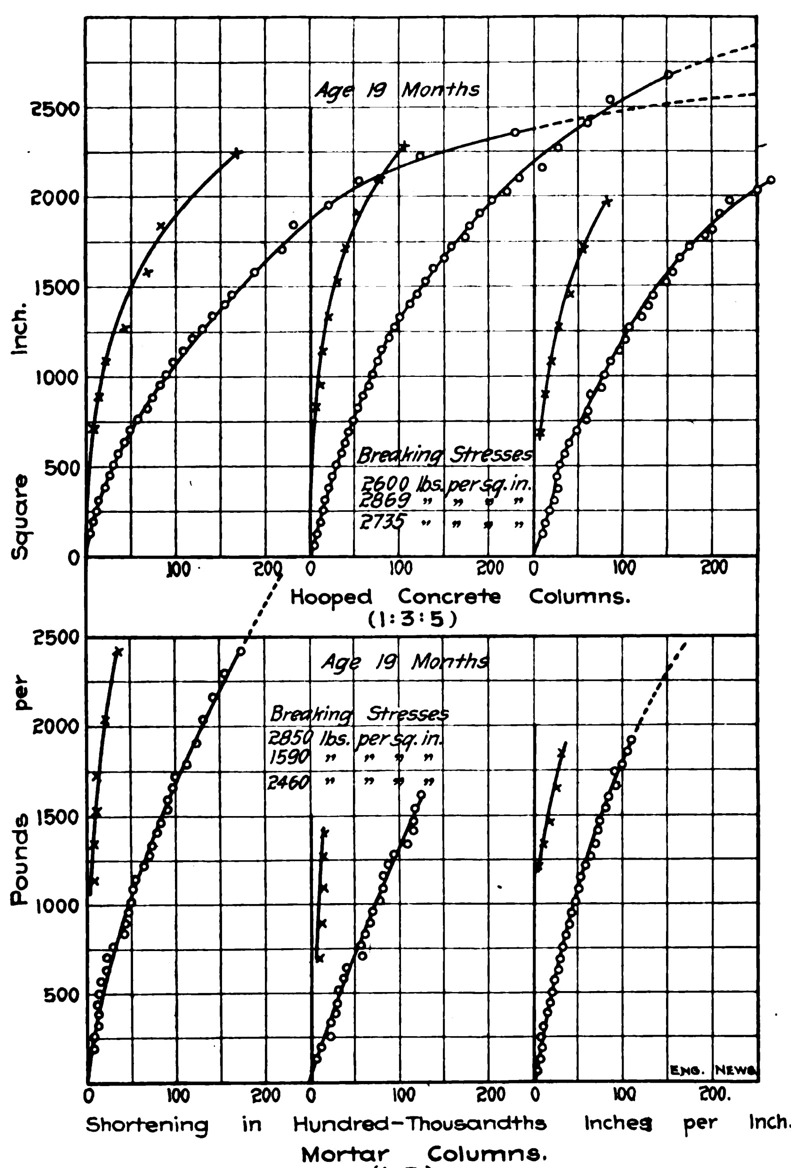
The cribs were made of 12 × 12-in. timbers dressed on two sides, and laid up solid. They were built to their full height about the piles and loaded with stone. The excavation was done with the ejector previously described. The penetration given the cribs varied from 15 to 20 ft. below the original level of the bottom, but the actual penetration, when sinking was completed, was only a few feet, owing to the scour and to the material drawn in from the outside by the ejector. This left the crib standing in a basin, which, in each case, was filled with paving rock, giving the piers a splendid protection below the original level of the bottom. After the cribs were landed they were sealed with from 5 to 10 ft. of rich concrete (1-2-3 mixture), deposited about the piles by steel pipe tremie. This concrete was allowed to stand one week, when the crib was pumped out and cleaned. The piles were then cut off 5 ft. below low-water level, with their tops at slightly irregular heights, after which the remainder of the concrete was brought up in the dry to the base of the cofferdam. The upper cross struts were removed ahead of the concrete.

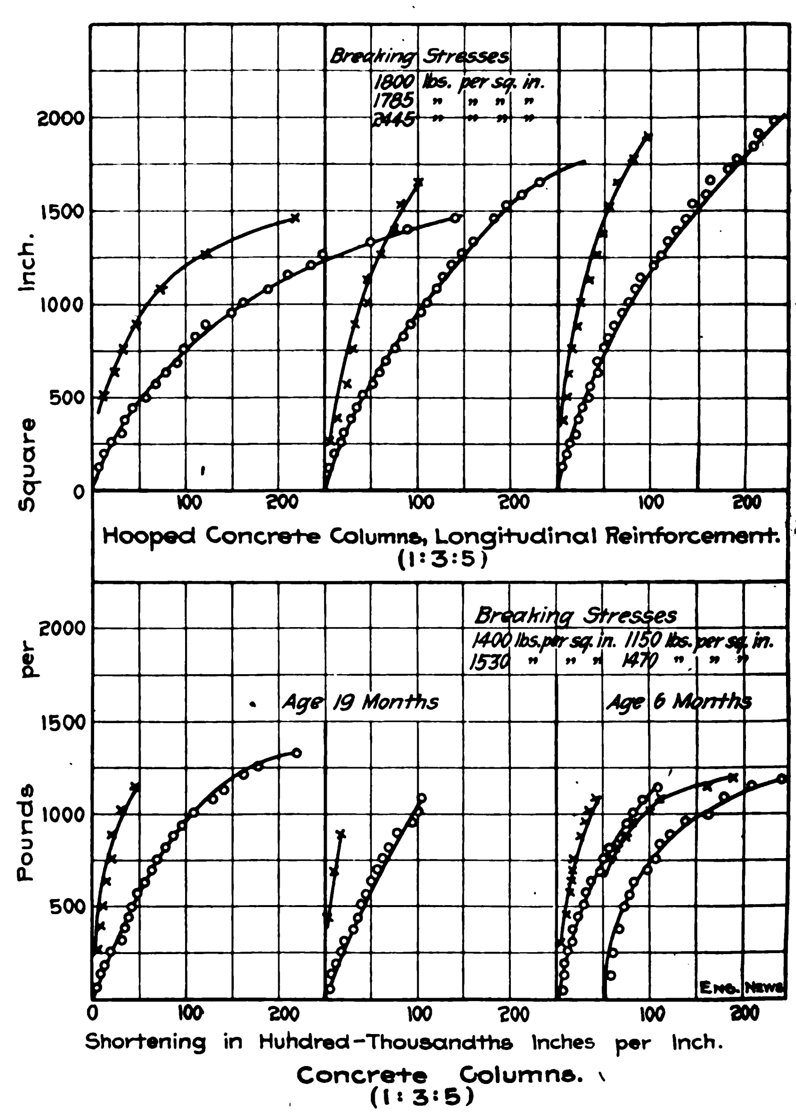
GENERAL REMARKS.—To carry out the work described, the contractors provided an almost model plant; the principal item was a machinery scow to which was located the boilers and pumps previously described, an air compressor and an electric light plant. Another scow carried the concrete materials and the mixing plant, and several tugs and scows were utilized in transporting materials. Work on the substructure was begun in August, 1902, and was completed in June, 1903.

RESULTS OF COMPARATIVE TESTS OF PLAIN AND REINFORCED CONCRETE COLUMNS.

By E. J. McCaustland.*

In modern building construction much use is made of the reinforced concrete column. The types of reinforcing are usually easily reduced to one of two general classes—a hooping in the form of a continuous spiral, or a series of independent hoops or loops. Longitudinal bars or rods may be used with either class. The pitch of the continuous spiral, and the spacing of the independent hoops are matters more or less empirical, and they must remain so for some time to come.





DIAGRAMS SHOWING RESULTS OF COMPARATIVE TESTS OF PLAIN AND REINFORCED CONCRETE COLUMNS.

In the field of experimentation, spiral hooping has been perhaps, more commonly used than the independent hoop. So far as the writer is aware, no comparative tests have been made of the relative efficiencies of the spiral and the loop form of hooping. It would appear from a casual consideration, that the closed hoop should induce in the specimen a higher ultimate strength and modulus of elasticity than would the spiral form: First, because in the case of the spiral hooping a shortening of the column in the direction of its axis will lessen the pitch of the spiral and enlarge its diameter, thus allowing an earlier disintegration of the material with consequent failure, and, second, because this change in the form of the spiral would allow a greater deformation of the material with a consequent drop in the modulus of elasticity of the column as a whole. Again, since concrete either plain or reinforced, takes a measurable amount of permanent set under comparatively light loads, it seems clear that the spiral form of reinforcing is the least fitted to oppose this action.

The effect of a series of steel hoops, spaced at a distance apart of about two-thirds of the diameter of the column they are designed to reinforce, is to divide the column into a series of short blocks and, thus, to develop a higher unit strength than could be obtained without the aid of such reinforcement. Longitudinal bars or rods used for reinforcement of columns will increase the crushing strength but slightly. Their main value is to provide an adequate resistance to any tensile stresses which may be developed as a result of flexure in the column. A very slight buckling of these longitudinal rods relieves them almost entirely of stress and reduces the resisting power of the column.

The following record of tests of plain and reinforced concrete columns is offered as a slight contribution to the general sum of our knowledge of the behavior of concrete and steel in combination.

The columns tested were 40 ins. long and 10 ins. in diameter. They were mixed in the proportions, by volume, of 1 part Alpha Portland cement, 3 parts bank sand and 5 parts broken limestone, using just sufficient water in the mixing to have it flush to the top of the molds when the concrete was tamped.

The mortar columns were made in the proportions of one part of cement to three parts of sand. Two kinds of reinforcement were used. In one set of three columns, eight hoops were used, each ⅛ × 2 ins. in section. These were spaced 5 ins. c. to c., the centers of the end hoops being placed 2½ ins. from the ends of the columns. Another set was reinforced with four hoops of the same sort, and eight longitudinal rods ¼ × 1 in. in section. These hoops were spaced 10 ins. c. to c. the end of the column being 5 ins. from the first hoop. The hoops were made with an outside diameter of 10 ins., and therefore were not embedded in the concrete. This is not the manner in which col-

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THE NEW WESTMINSTER BRIDGE OVER THE FRASER RIVER, BRITISH COLUMBIA.

Superstructure and Erection.

The foundations for the new highway and railway bridge over the Fraser River at New Westminster, British Columbia, were described in detail in Engineering News of June 15, 1905. As noted in that description, these foundations, because of their depth and the methods employed in sinking them, place the structure among the notable bridges of the world. So far as the superstructure is concerned, the bridge is notable chiefly for the special "spread" span designed to accommodate a Y-track and for the methods adopted in erecting the several spans. A diagram elevation of the bridge was given in the previous article; here only the details of the "spread" span and illustrations of the mode of erection are presented. The first page picture is a view of the completed bridge.

GENERAL DESCRIPTION.—The location of the bridge is in the city of New Westminster, B. C., the bridge tangent being placed about where a continuation of Dufferin St. would strike the river bank and at about right angles to the average direction of current. It crosses overhead the track of the Canadian Pacific Ry. on the city side of the river and that of the Great Northern Ry. on the opposite, both tracks being close to the river banks. The structure will carry wagon traffic on an upper deck and steam railway and motor traffic on the lower deck. At a point on the lower deck about 300 ft. from the water's edge on the New Westminster side, or directly over Pier III, the railway track divides, turning to right and left on 12° 30′ curves, thus forming a Y. On this account, the shore span, while only 19 ft. wide between centers of pedestals over Pier III, is about 136 ft. wide between pedestals over Pier II.

Beginning at Pier II and proceeding toward the south bank of the river, there are the following spans: One through fixed span of 225 ft.; one through fixed span of 380 ft.; one through swing span of 380 ft., and five through fixed spans of 159 ft. each. Next there is a wooden trestle carrying separately highway, railway and motor traffic, and extending across the Great Northern Railway track. Beginning at Pier II and proceeding toward the north or New Westminster bank of the river, there are the following spans: East arm of Y: two deck plate girder skew spans of 75 ft. each, one-half through skew span of 48 ft., and one deck plate girder skew span of 68 ft. West arm of Y: one deck plate girder skew span of 75 ft., one similar span of 48 ft., one-half through plate girder skew span of 25½ ft., and one deck plate girder skew span of 40 ft. Highway structure: one deck plate girder span of 96 ft., and two of 40 ft. each.

Steel bents are used to support all railway spans that cross the railroad track and for the three highway spans at the north end of structure; otherwise all spans are supported on masonry or concrete piers and abutments. The clear roadway for both the railway and the highway is 16 ft., thus making the perpendicular distance between central planes of trusses 19 ft. for the 380-ft. spans and 18 ft. for the 159-ft. spans. The five 159-ft. spans carry the highway above the top chords, while the three longer spans carry it about mid-height of trusses. The motor track joins the railway track of the west arm of the Y on the embankment, and runs over the railway until the wooden trestle is reached, where it diverges to the west and runs parallel to it until the embankment is reached. The highway track does not cover the railway track until just before it reaches Pier III, and it leaves it again when it comes to the wooden trestle; there it turns to the east so as to parallel the railway on a descending grade. It crosses the Great Northern Ry. track overhead, and soon after reaches the earth embankment. The railway and motor floors consist of the ordinary timber ties and guards carrying 75-lb. rails, all as shown on the drawings. The highway floor consists of longitudinal wooden joists carrying a tight double thickness of plank flooring, the lower thickness running diagonally and the upper transversely of the span. Of the main structure the 159-ft. spans have riveted connections; the others are all pin-connected.

BRIDGE ACROSS THE FRASER RIVER AT NEW WESTMINSTER, BRITISH COLUMBIA.

SPREAD SPAN.—The spread span between piers II and III calls for some special notice. As already stated, the trusses of this span are 19 ft. apart at one end and 136 ft. apart at the other end. Fig. 1 is a detail of one of the trusses showing the strains in the various members and the sections adopted to withstand them. Fig. 2 is a half plan of the upper lateral bracing between trusses and Fig. 3 is a similar plan of the upper lateral bracing. These drawings are complete and call for no further explanation. The floor construction is shown by the drawings of Fig. 4. As will be seen the bottoms of all vertical posts are dropped below the bottom chords in order to receive the ends of the cross-girders. These are either plate or box girders and are of varying depths according to their lengths. Their exact dimensions are shown by the drawings. The longitudinal girders carrying the tracks rivet into the cross-girders and the latter also carry the bents which support the highway floor. The details of the bracing between the track girders are shown clearly by the drawings. The material used in the spread span and throughout the bridge is medium steel of from 60,000 lbs. to 70,000 lbs. ultimate strength, and the requirements for testing, workmanship, etc., were those of Mr. J. A. L. Waddell's well-known specifications.

ERECTION.—The erection of the superstructure calls for particular mention in respect to the spread span and the 380-ft. fixed span only. These spans were floated into position from falseworks on which they had been erected complete. The swing span and the five 159-ft. fixed spans were erected on falseworks between the permanent piers, but this method could not be readily adopted for the remaining two spans because of the depth of water between piers II. and IV.

Considering first the 380-ft. fixed span, it will be noted that it is of exactly the same length as the swing span which it was designed to erect on falseworks. This made it possible to erect both spans on the same falseworks, erecting the fixed span first and then floating it off and to its permanent position to give room for the erection of the swing span. To provide for floating off the fixed span the falseworks were made with four openings wide enough to admit four scows. These scows were floated into position at low tide, 6 a. m., Nov 11, 1903, and as soon as they were placed, work was begun pumping out the water that had been admitted to partially submerge them. At 9:20 a. m. the span was lifted clear of the falseworks and at 9:40 a. m. two tugs started to tow it upstream. As soon as the span had been towed clear of the falsework it was gradually moved transversely across the stream until it was opposite its permanent supports, piers III. and IV. It was then dropped down stream between the piers. At 10:20 a. m. the span stood over the piers, the moving having consumed 40 minutes.* The fixed end was first landed by admitting water into the scows near that end, and then the roller end was landed by a similar process with the other two scows. The span was finally in position at 2:30 p. m.; the metal work of the span weighed 788 tons and the load carried by the scows was 825 tons, not including the supporting scows and bents. The view, Fig. 5, shows the spans being floated into position and explains the arrangement of the scows and of the trestle bents carrying the span.

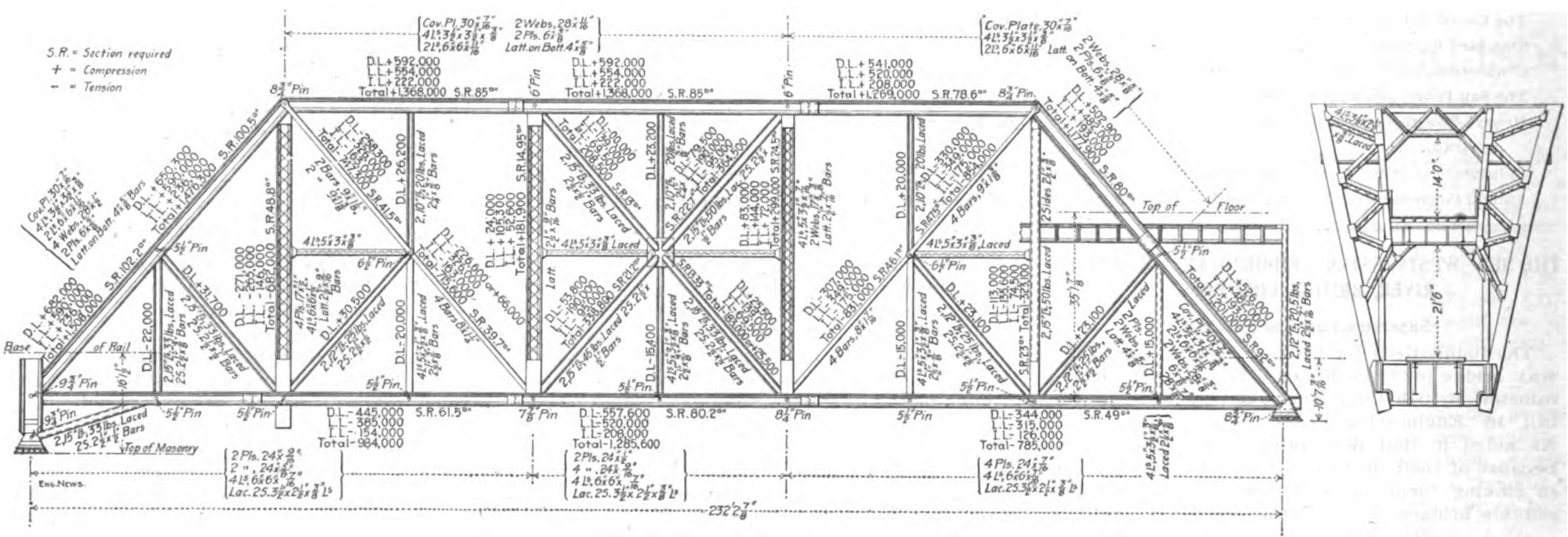


FIG. 1. DETAILS OF SPREAD SPAN TRUSS, FRASER RIVER BRIDGE.

As the current on the north side of the river, under the position to be occupied by the spread span, runs at from 4 to 5 miles per hour, and the depth of water at this point is 80 ft., it was decided that the span could not, with safety, be erected on falsework in its final position. It was therefore planned to erect the span on the south side of river where the depth of water was about 25 ft., and where it was possible to erect substantial falseworks.

The first truss was erected on a line parallel to one of the previously erected 159-ft. spans, on the down-stream side and 12 ft. away. The steel for the truss was brought out over the highway roadway and then handled by a single mast derrick having three booms. The heaviest piece handled was a section of top chord weighing 13¼ tons. The derrick when handling loads was held down by cast steel anchor hooks catching under the top chords of the 159-ft. spans.

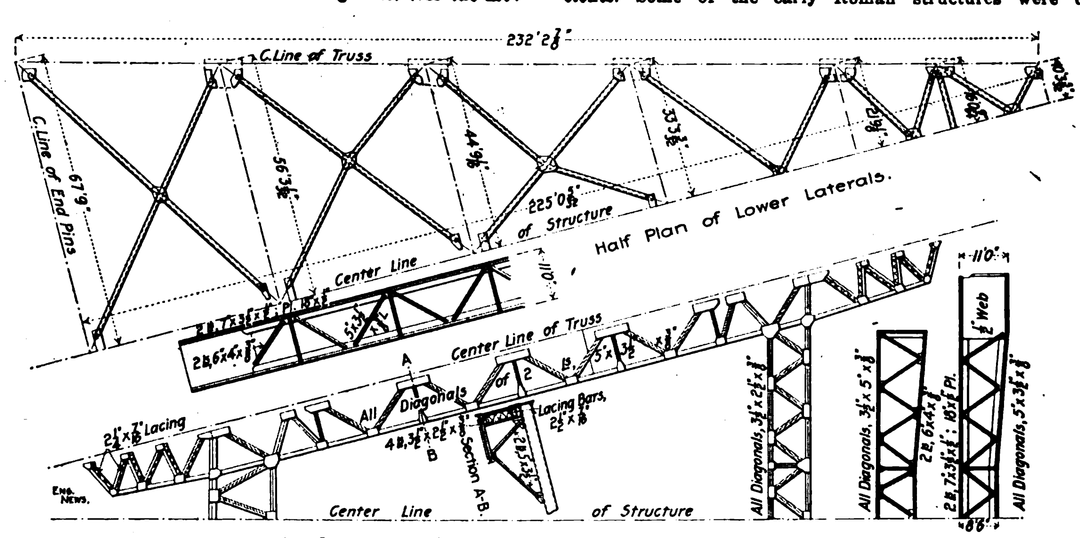
When the first truss was coupled up, preparations were begun for moving it to temporary pile piers which had been driven to receive it. These piers, together with a double intermediate bent, were carefully located with reference to the line upon which the truss had been erected. The intermediate bent was not only to support the truss, but was built so wide that from it batter braces were run to the top chord to hold the truss against overturning. In addition to the braces the truss was held upright by four sets of triple blocks running from the hip points, two from each side of truss, those from up-stream side running to the steel work of the 159-ft. span, and those from down-stream side running to two pile dolphins.

The two scows, each 30 × 90 × 8 ft., into which 2 ft. of water had been admitted, were placed under the truss at low tide. As soon as they were correctly set, eight diaphragm pumps, four to each scow, were started and the water was removed as quickly as possible. The scows were placed under at 5.30 a. m. and the truss was landed at 12 m. The landing was hastened by the admission of water to the scows. The truss, as it was floated, weighed 235 tons. The tension members and substruts, which were subjected to a compression stress due to the position of scows while floating, were stiffened to take the load.

After floating the first truss, the second was erected in the position formerly occupied by the first one, and the two were connected by the floor beams at the narrow end of the span and by the top lateral bracing.

To float the erected span into place, three scows were arranged under it in the positions shown by Fig. 6. The details of the process are explained by the following excerpt from the engineer's diary:

March 19, 1904.—Moved spread span this morning. The three scows were placed in position at 2 a. m., low tide occurring shortly after that time. Three (3) feet of water was admitted to each scow yesterday. The removal of this water was begun as soon as the scows were in place. There were five diaphragm pumps in each scow. At 5.15 a. m. the span was clear of its bearings. At 7.45 the moving of the span was begun and at 9.40 a. m. the span was over its piers. At 11.50 a. m. the four shoes were landed. The scows were removed later in the afternoon at low tide. Water admitted into scows to hasten the landing.



Half Plan of Upper Laterals.

FIGS. 2 AND 3. UPPER AND LOWER LATERAL BRACING FOR SPREAD SPANS.

The weight of the span as it was floated into position was 500 tons. The appearance of the span afloat is shown clearly by Fig. 6. The two scows at the wide end were each 30 × 90 × 8 ft., and the scow at the narrow end was 30 × 106 × 8 ft.

After the span had been seated on the piers, there remained to be erected the heavy floor girders and the stringers connecting them. The view, Fig. 7, shows this work in progress, the traveler shown being used to place the stringers and lower laterals. Counting from the near end of the span the floor girders in order weigh 87 tons, 77 tons, 55 tons, and 31 tons, respectively. They were all erected on falseworks of the type shown in the view.

As stated in the previous article, the contractor for the superstructure was the Dominion Bridge Co., of Montreal, Canada. This company did the erection work described. Mr. M. W. Julien being the foreman in direct charge. The engineers of the bridge were Waddell & Hedrick, of Kansas City, Mo. We are indebted to Harry K. Seltzer, their Resident Engineer, for the information from which this account of its construction has been prepared.

THE EVOLUTION OF THE PRACTICE OF AMERICAN BRIDGE BUILDING.*

By C. C. Schneider, President, Am. Soc. C. E.

In the time-honored custom of an address by the President at the Annual Convention of the American Society of Civil Engineers, many of my predecessors have selected topics with which they were most familiar. My life work naturally suggests to me the title of this address.

The magnificent stone bridges and aqueducts built by the Romans bear evidence that the art of bridge building had reached a high degree of perfection among the ancients. Some of the early Roman structures were of gigantic proportions, and have not been excelled by any of those built in modern times. There are no records to show that the ancients had any theoretical knowledge of bridge construction; they built their bridges in accordance with empirical rules developed by experience. These monuments of engineering skill, which have lasted for thousands of years appear marvelous to the modern engineer, who has at his command, not only theoretical knowledge, but also mechanical appliances and modern tools to assist him, which were not known in ancient times. The progress, therefore, made in the art of constructing bridges of stone in modern times ap-

*Presidential address before the American Society of Civil Engineers at the Annual Convention at Cleveland, Ohio, June 20, 1905.

pears insignificant, and is practically confined to theoretical knowledge and improvements in machinery and tools for handling material.

The development of the art of bridge construction is marked to a certain extent by periods coincident either with the introduction of new materials or with the necessities arising for means of transportation. The marvelous progress made in bridge building in the 19th century—the century of engineering, of the manufacture of power, of the railroad and the telegraph—really began with the production of wrought iron in large quantities, and has since kept pace with the development and progress made in the manufacture of those most useful and precious of all metals, wrought iron and steel.

The various types of bridges which have survived and become the standard types of the present day are the results of the evolution of a century, originating with the wooden bridge, the wooden beam being the prototype of the modern plate girder, and the framed wooden truss that of the steel truss. Timber bridges, consisting of hewed logs, supported by piers of piling or of stone, were erected in the earliest times in all countries where timber was abundant, Caesar's bridge across the Rhine was of this character. The wooden bridge consisting of framed trusses is the product of more modern times.

In Europe, wooden truss bridges of small span, patterned after existing roof trusses, have been built for several centuries. In America, however, it was not until the end of the 18th century that the movement began to which the present type of bridges can be traced.

There appear to be no records of any wooden bridges in America before 1785, when unusually gifted men like Palmer, Burr, Wernwag and others commenced to build some very remarkable wooden structures. The progress made in bridge building in this country was very slow until railroad building commenced, which was in 1829, when the construction of the Baltimore and Ohio Railroad was begun. The first wooden railroad bridge was built on that road in 1830 by Wernwag, at Monaguay. The development of railroads naturally created a demand for bridges.

The difficulties and obstacles encountered in crossing long and deep valleys were overcome by these pioneer railroad builders by erecting temporary timber trestles in place of expensive embankments or viaducts, to be filled in or rebuilt by permanent structures at a later period. The timber trestle, therefore, is a distinctly American type of construction, and is the prototype of the iron viaduct. Some of the first high wooden trestles were built in 1840 on the Lake Schuylkill and Susquehanna Railroad, now the Catawissa Branch of the Philadelphia and Reading Railroad. They were designed by James F. Smith, and their heights varied from 60 to 130 ft.

The forms of timber trusses of different kinds, arches and combinations of two or more systems, have been very numerous. A marked step toward bridge designs of the modern truss form was the lattice bridge patented by Towne in 1820, which became the prototype of the early iron lattice bridge. The next important step in the development of wooden bridges was made in 1840, when Howe patented his truss, which became very popular and the standard for wooden railroad bridges. In 1844, the Pratt truss was patented, which afterward became the favored type for iron bridges. Many other types of trusses were invented, which have since been discarded.

The earliest wooden bridges were built by expert carpenters. The work was done by contract, very much the same as building work is done at the present day, except that the builder was also the designer. The builder would buy suitable timber or have it sawed to order at conveniently located saw-mills, and any ironwork needed in the construction of the bridge, such as rods, bolts or bars, he would obtain at a local blacksmith shop, and frame and erect the bridge in place, ready for traffic. The same methods were also used in building the early iron highway bridges. Each of these builders had his own type of bridge and his own special details. At that time there was generally but little competition, as very few had any knowledge of bridge building, and each one controlled a certain territory.

All the early railroad bridges were wooden structures built by practical carpenters, in most cases employees of the railroad company.

England is considered as the pioneer country of the iron bridge, the first one, consisting of a nearly semicircular cast-iron arch, having been built in 1776-79. In 1786, Thomas Paine, the well-known author, designed and made a model of a segmental arch. This model was set up at Franklin's house in Philadelphia, whence it was taken to the State House, and, eventually, was sent to Paris and exhibited at the Academy of Sciences. Paine had an experimental cast-iron bridge built in England in 1790, and Rowland Burdon, in 1793 to 1796, built the bridge at Wearmouth, of 240 ft. clear span, after this model, which formed the basis of many cast-iron bridges built thereafter, and became the prototype of the modern steel arch. Paine's device was also the basis of the design of the Market Street Bridge and the first Fairmount Bridge, in Philadelphia, both being wooden arches. The former was completed in 1800, and the latter in 1812.

Up to 1840, there were no iron bridges in this country, except suspension bridges in which iron links were used in the cables and suspenders, the floor-system being of wood. The first bridge in America consisting of iron throughout was built in 1840 by Earl Trumbull over the Erie Canal, in the Village of Frankfort, N. Y. In the same year Squire Whipple, Hon. M. Am. Soc. C. E., also built his first iron truss bridge.

Probably the first iron railroad bridge was built on the Philadelphia and Reading Railroad at Manayunk by Richard B. Osborne, Chief Engineer, in 1845. It was a double-track through bridge, of 34 ft. clear span, of the Howe truss type, with cast-iron top chord and web braces, the bottom chord and vertical web members being of wrought iron. This bridge was followed by several others of the same type.

The earlier wooden and iron bridges were built very much in the same manner as the ancient Roman bridges, in accordance with empirical rules, by practical men who had no accurate knowledge of the strains produced on the various members of a structure by the exterior forces, but who were men of unusual constructive ability and

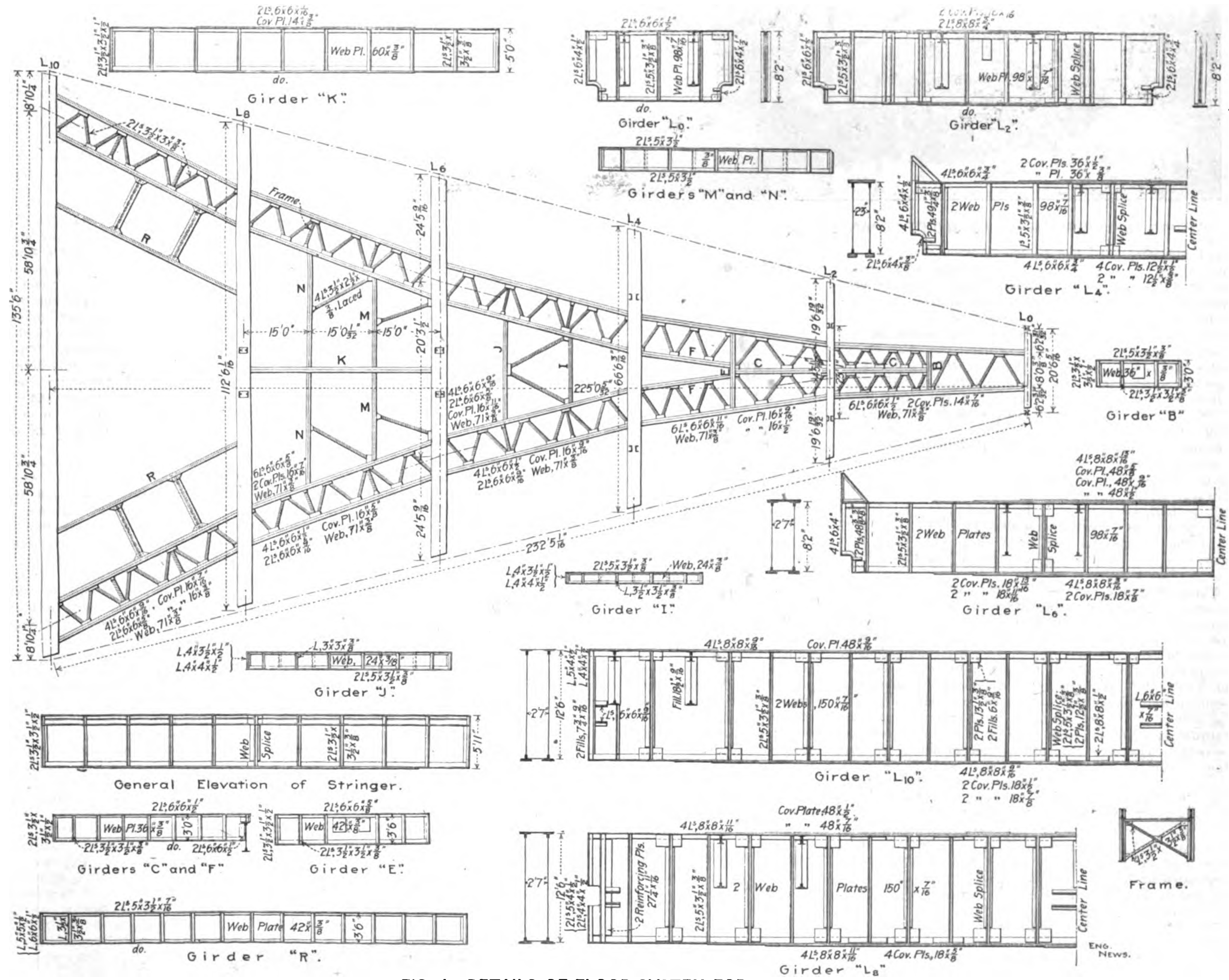


FIG. 4. DETAILS OF FLOOR SYSTEM FOR SPREAD SPAN.

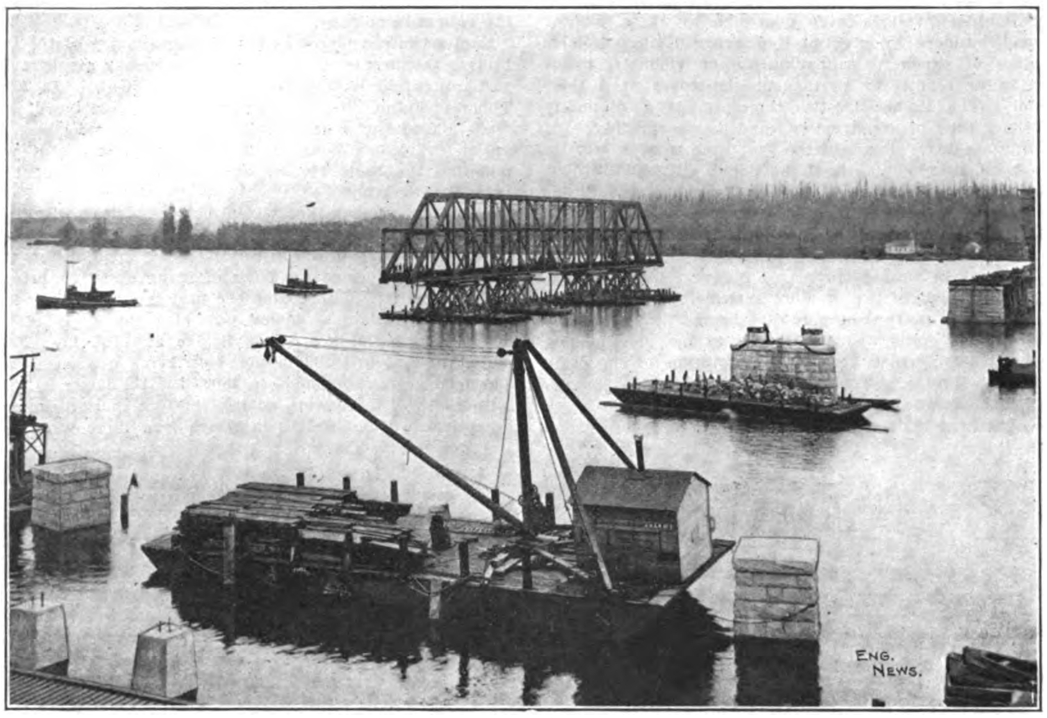


FIG. 5. VIEW SHOWING 380-FT. SPAN BEING FLOATED INTO PLACE ON BARGES.

sound judgment, who had to depend upon their own resources and natural instinct, experimenting with models and profiting by previous failures. Pratice always preceded the science, thus the structural systems were invented before their theory was developed.

Until 1847, when Squire Whipple, the modest mathematical instrument maker, who, without precedent or example, evolved the scientific basis of bridge building in America, correct methods of computing the strains in framed structures were not known. A few years later, in 1851, Herman Haupt published a book on the theory of bridge construction.

About 1850, after the building of railroads had advanced, the educated engineer commenced to exert his influence in the art of bridge building, and, from that time forward, steady progress was made. The period from 1850 to 1860, therefore, may be regarded as an epoch in the history of American bridge building; the time when the bridges designed by Fink and Bollman first came into use, and the earliest iron Whipple and Pratt trusses were built.

When American engineers commenced to build iron bridges, they paid little attention to the then existing European models, but preferred to develop their own systems independently, as they had done previously with wooden bridges, the first iron bridges being imitations of the Towne lattice, and the Howe and Pratt trusses. All the earlier bridges were built principally of cast iron, wrought iron being used in tension members only. In the first iron viaduct built by the Baltimore and Ohio Railroad, in 1852, all parts were of cast iron, except the tie-rods. The wrought-iron tension members at that time usually consisted of round bars with screw ends, or elongated links made of square bars. Later, these links developed into forged eye-bars, introduced by J. H. Linville, M. Am. Soc C. E., in 1861. These eye-bars have since become one of the distinctive features in American bridge construction. Although flat eye-bars were used in Europe at an earlier period, in chains of suspension bridges and in some types of trusses, they did not find favor there, and were soon discarded for structures with riveted connections.

The first bridges made entirely of wrought iron were those of the riveted lattice type which Howard Carroll, then Assistant to George E. Gray, Hon. M. Am. Soc. C. E., Chief Engineer of the New York Central Railroad, commenced to build in 1859; next came the plate-girder type, the first of which was built by E. S. Philbrick, M. Am. Soc. C. E., for the Boston and Albany Railroad in 1860.

The bridge built by J. W. Murphy in 1863, over the Lehigh River at Mauch Chunk, for the Lehigh Valley Railroad, was the first pin-connected bridge constructed entirely of wrought iron in its main members; cast iron being used only for joint boxes connecting the compression members. Many bridges of similar construction were built after this, but it was not until after the failure of the Ashtabula Bridge, in 1876, that cast iron was entirely discarded as too unreliable a material to be used in any parts of a railroad bridge.

Prior to 1860, railroad bridges were generally designed by the railroad companies' engineers, the ironwork being manufactured at the companies' shops, and erected by their own forces. Thus, men like Wendell Bollman, Albert Fink, Past-President, Am. Soc. C. E.; C. Shaler Smith, M. Am. Soc. C. E., and C. H. Latrobe, M. Am. Soc. C. E., on the Baltimore and Ohio Railroad; Richard B. Osborn and Charles Macdonald, M. Am. Soc. C. E., on the Philadelphia and Reading Railroad; J. H. Linville, on the Pennsylvania Railroad; E. S. Philbrick, on the Boston and Albany Railroad; George E. Gray, Howard Carroll and Charles Hilton, on the New York Central Railroad; Williard S. Pope, M. Am. Soc. C. E., on the Chicago and Northwestern Railroad; Thomas C. Clarke, Past-President, Am. Soc. C. E., on the Chicago, Burlington and Quincy Railroad; S. S. Post, M. Am. Soc. C. E., on the Erie Railroad, were prominent railroad engineers who took a leading part in early bridge building.

Later, some of the men who had gained experience in framing and erecting bridges, or in the construction of the work at the shops, started in business for themselves, and took contracts to build and erect bridges on designs furnished by the railroad companies' engineers. Most of those early firms were contractors for building Howe truss bridges, only a small shop being required to manufacture the ironwork needed for structures of that class.

Some of the bridge engineers employed on railroads, seeing that they could use their knowledge to better advantage in the more profitable business of contracting, associated themselves with the then existing bridge building firms, or organized new companies. These new companies often made a specialty of manufacturing constructions of a certain type, expressing the individuality of the engineer at their head, and which were his own inventions, in many cases controlled by patents. They were able to furnish designs for bridges, as well as construct and erect them. Most of those companies were organized between 1860 and 1870, which period, therefore, forms another epoch in the history of American bridge building.

Near the end of the 60's, when most of the early bridge companies had been formed, there were, besides the engineers interested in bridge building firms, only a few experienced bridge engineers in this country. The engineers who were at that time connected with bridge companies were mostly men who had gained their experience in the employ of some railroad company, had worked out their own type of construction, and had experience, not only in designing, but also in superintending the construction and erection of bridge work. Their theoretical knowledge, measured with the present standard, was limited to elementary methods, but their thorough practical training enabled them to combine theory and practice to the best advantage. They understood how to make their designs conform to the methods of the workshop, as well as to facilitate erection. This was really the beginning of the development of American bridge building and of the distinctly American types of construction which at that time differed so materially from those of other countries.

The most distinguishing feature of the methods then prevailing in this country, as compared with those of other countries, the influence of which is felt to the present day, is that at that time in America the bridges were designed by experienced specialists, and the work was constructed in shops built and equipped for that special purpose by experienced mechanics trained in that class of work. At first these companies controlled the work in certain territories, or the contracts were awarded to them on account of the reputation of their engineer. However, as competition became keener, railroads desired to purchase their bridges for the lowest price, and invited several firms or companies to submit tenders on the bidders' own designs, which started the competitive system of designing and bidding on bridge work.

Up to about 1872, specifications, as we now understand the term, were not in general use. An invitation to bid on bridge work would be accompanied by a survey plan, giving the length of the spans, skews, etc., and a statement of the live load the bridge was to carry, generally a uniform load of 1 ton per linear foot, with a factor of safety of 5. The design of the structure and the proportioning of its members and their details and connections were left entirely to the judgment of the builder, and accepted without question by the purchaser. These builders, who at that time were about the only bridge experts in America, were considered authorities, and would assume the responsibility for the design and the strength of the bridge for the specified loading. In other words, the bridges were accepted on faith and on the strength of the reputation of the builder.

From 1864 to about 1874, the designing of bridges was almost entirely in the hands of the bridge-building firms, only a few railroads, such as the Pennsylvania, and Boston & Albany, employing their own bridge engineers to prepare the designs and to supervise the construction of bridges and other structural work on their respective roads. The contracts for bridges were then let on a lump-sum price for the work erected in place. It was therefore to the interest of the bridge builder to make designs which would reduce the cost of shop work, as well as that of erection, and, as the price of wrought iron was high, as compared with the price of steel at the present time, the saving of material was one of the most important considerations in the designing of bridges.

At that time railroad construction had commenced to develop rapidly in all parts of the country, and many wide and treacherous rivers had to be spanned with bridges. The material for these bridges had to be transported to distant places, erected in unsettled locations, and the ironwork manufactured and erected rapidly in order to keep pace with the swift progress made in the building of railroads. As the pin-connected type ful-

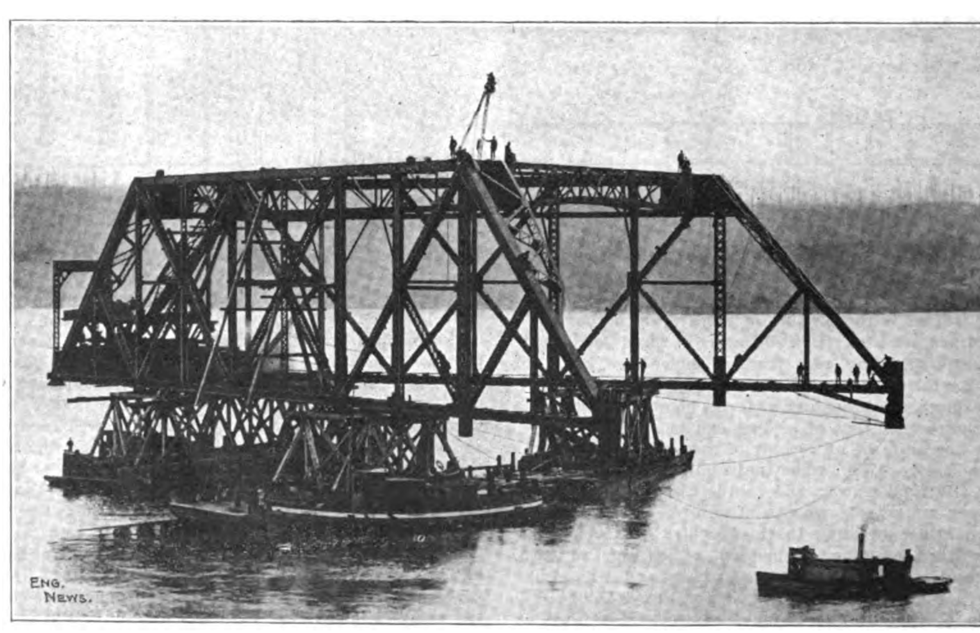


FIG. 6. SPREAD SPAN BEING FLOATED INTO PLACE ON BARGES.

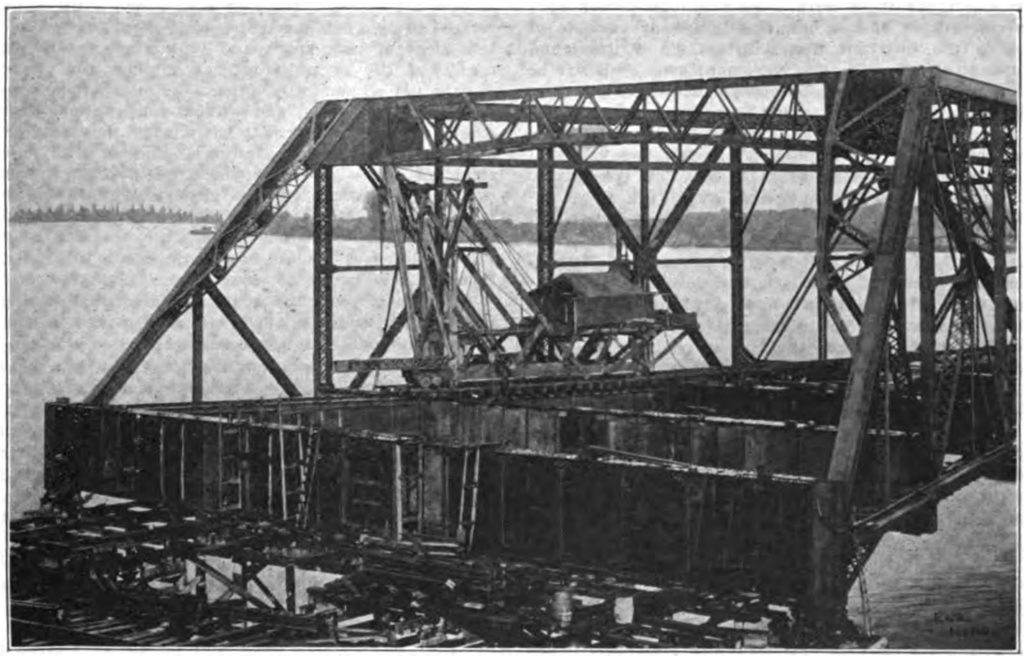


FIG. 7. VIEW SHOWING ERECTION OF FLOOR SYSTEM FOR SPREAD SPAN.

filled, more than any other, these requirements, viz., economy in weight and facility in manufacture and erection, thereby not only reducing the cost, but also the risks and dangers of erection, it became the favorite type of bridge, and has remained so for long spans to the present day.

The first more comprehensive specifications were those published by Clarke, Reeves & Co., in 1871. In 1873, George S. Morison, Past-President, Am. Soc. C. E., prepared specifications for the Erie Railroad, which were probably the first printed specifications for iron bridges adopted by any American railroad. In 1875, L. F. G. Bouscaren, M. Am. Soc. C. E., wrote specifications for the Cincinnati Southern Ry., the first in which concentrated wheel loads were specified for the live load. Mr. Morison established the practise, on the Erie Railroad, of requiring the successful bidder to submit strain sheets and plans for approval before ordering material or commencing work. These plans, before being approved by the chief engineer, were examined by one of the assistant engineers, and, later, the material and workmanship were inspected by men in the employ of the railroad. The same practice was also adopted by Mr. Bouscaren on the Cincinnati Southern Ry.

The year 1873, therefore, may be considered as marking the beginning of another epoch, viz., that of the bridge engineer as again acting in the interests of the railroad company, and also the beginning of the inspection of structural ironwork. Before that date the St. Louis Bridge was probably the only case on the construction of which inspectors of material and workmanship were employed.

Many new bridge companies were established after 1874, some of which had a marked influence in the development of American bridge construction, as well as in the improvement of tools and machinery, resulting in a higher grade of work. Some of the engineers who had gained experience in the emnloy of bridge companies obtained positions on railroads as bridge engineers; others, particularly the most competent, left the employ of bridge companies for private practice, and devoted themselves to the specialty of structural engineering, acting in the interests of corporations and municipalities or other purchasers of iron structures.

These corporations commenced to realize that it would be to their advantage to have the services and advice of competent specialists. Thus, in 1876, the existence of the bridge engineer and structural expert, independent of a bridge company, had become an established fact.

After iron railroad bridges had been in service for about twenty years, engineers who had charge of their maintenance noticed that weak points developed under traffic, particularly in the details and connections. It also became apparent that the bridges built, up to about 1875, were deficient in rigidity and lateral stability, and improvements were gradually made to remedy these defects, producing more massive construction, fewer and heavier parts, and a more extensive use of riveted connections. The pin-connected type of truss for short spans was gradually discarded, the plate girder and riveted truss taking its place, and the limiting length of spans for these types was gradually increased. Specifications for iron bridges were also revised and improved; those prepared in 1877 by Charles Hilton for the Lake Shore and Michigan Southern, and by C. Shaler Smith for the Chicago, Milwaukee and St. Paul Railroad, and 1879 by Theodore Cooper for the Erie Railroad, being steps in that direction.

Steel, as a structural material was first used in a portion of the St. Louis Bridge, completed in 1874, but the first bridge built entirely of steel was the Glasgow Bridge, over the Missouri River, completed in 1879. The extensive use of steel, however, did not commence until 1890. Before that time steel was used only in isolated cases, or for heavy work, such as chords and eye-bars for large spans.

About 1890, some railroads commenced to build also smaller spans and plate girders of steel, and, for eye-bars, steel was almost exclusively used. At that time most of the rolling mills, which had formerly manufactured wrought iron, were equipped with steel furnaces, but continued for some time to make both kinds of material, until they found it more profitable to confine themselves to the manufacture of structural steel only, and discontinued the manufacture of wrought iron. In 1894, it was practically impossible to obtain wrought iron shapes, and from that time forward steel entirely superseded wrought iron as the modern structural material. The year 1894, therefore, may be considered as the commencement of the present epoch—the steel age.

The use of steel in the construction of modern bridges, and the improvements made in its manufacture, thereby reducing its cost and increasing its reliability, have made it practicable to build structures of a magnitude never attempted before. Its introduction as a structural material had a marked influence on the progress and development of bridge building. Certain types of construction and details which have proved unsatisfactory have been discarded, and others which have undergone a process of purification and improvement have survived. Rational types of construction and details are now established, and have become the recognized standards for ordinary bridges of moderate spans. The present tendency is toward uniformity, and to-day there is but little difference between the designs made by competent engineers.

This tendency toward uniformity has also been extended to specifications for bridges and other steel structures, relating to quality of material, workmanship and unit strains. As late as five years ago, the requirements specified for the quality of steel were numerous, almost every railroad or bridge engineer requiring some different grade, and sometimes several different kinds in different parts of the same structure. Erratic specifications are now gradually disappearing, and engineers at the present time are nearly all agreed on the grade of steel best suited for structural work.

There is also at present more uniformity between the designs made by American engineers and those by European engineers. In the early days of iron bridge building, in this country, there was little resemblance between American and European structures. Each country gradually adopted the good points of the other's practice; we adopted their practice in the use of riveted trusses for longer spans and a more extensive use of riveted connections; while the European engineers are adopting the more rational designs and details of plate-girder and riveted-truss construction now used in America. At the present time, the designs of plate girders and ordinary riveted-truss bridges, made in this country, are almost identical with the designs made by the best bridge engineers in Europe, so that no vital difference now exists between American and European bridges of moderate spans.

The steady increase in the weights of locomotives and rolling stock has been the cause of constant replacements of iron and steel railroad bridges by heavier structures. As the extreme limit of loads may not yet have been reached, the probable future increase should be anticipated in designing new bridges which have to carry any kind of railroad traffic. While it is impracticable to provide for all possible emergencies, railroad bridges should be designed to withstand the ordinary contingencies of traffic, such as derailment, a broken axle or a collision on the bridge. Structures designed in accordance with good practice may be damaged by such accidents, but should be able to stand up without collapsing. As steel is practically an indestructible material, if kept from corrosion, there is no good reason why properly designed steel bridges, properly protected, should not last at least as long as stone bridges in this climate.

About 1886, a new type of iron structure came into existence, viz., the iron skeleton construction for buildings, which has opened a new field for the structural engineer. The designing and construction of the structural part of these buildings has now become an important branch of engineering.

Any engineer who has followed the progress of American bridge building for the last 35 years must have observed that, not only the designs, but also the methods adopted for accomplishing results, have undergone a vast transformation; while, abroad, the designs have been improved, but the methods have changed very little, if at all.

The practice of having the designs of bridges and other structures made by engineers employed by the purchaser, and letting the contract to a manufacturer on a pound-price basis is now becoming the standard practice of the country. Most of the large railroads have their own bridge and structural departments, or, for work of unusual magnitude, employ outside experts to design and supervise construction. Only a few of the smallest railroads adhere to the ancient practice of inviting manufacturers to submit competitive designs accompanied by a lump-sum bid.

The competitive system has had its day and has served a good purpose. It has been an important factor in developing the art of bridge building in America. It has been productive of establishing rational types, practical details and scientific proportions; it has united theory and practice. However, at present, it is fast becoming a thing of the past. What is left of this practice is mostly confined to bridges for electric railways and light structural work. Many purchasers of structural work, who have had no experience themselves, do not seek professional advice, as they would in other cases where large expenditures of money are involved, believing that they can save the money paid for professional services by inviting manufacturers to make competitive designs accompanied by a lump-sum bid.

The fact is, however, that the manufacturer has to pay for making the designs not only once, but many times over, as only once in a number of cases he is the successful bidder. The manufacturer will naturally add this extra expense to the cost of the structure, yet the designs are not made in the interest of the purchaser, but in that of the manufacturer. This practice has a demoralizing influence, as it puts a premium on the poorest design and tends to decrease the professional standard of an important branch of engineering.

The standard practice to be recommended, as the only fair and business-like method, is to let contracts for structural steelwork on a pound-price basis, on designs and specifications furnished by an experienced engineer employed by the purchaser. This method is fair to the honest manufacturer, as all competitors bid on the same basis; it is an advantage to the purchaser, as he employs the engineer who will protect his interests, study the conditions and requirements, and design a structure to suit the needs of his client. It will benefit a number of engineers, who are now compelled to waste their time and energies in making speculative designs to suit the commercial interests of a manufacturer, regardless of good practice, by elevating them to more independent positions, thus enabling them to raise their professional standards to the highest ideals of good practice.

Plans for bridges and other structures, on the safety of which the lives of human beings depend, should be designed and not manufactured; their design and the supervision of their construction should be entrusted only to competent engineers, who, besides the requisite theoretical and practical knowledge, should, above all, be endowed with common sense and good practical judgment.

Most of the largest bridges and other steel structures which have been built in later years have been designed by engineers not connected with manufacturing establishments. The manufacturer should confine himself to his legitimate field of manufacturing structural steelwork at so much a pound. The line between engineers and manufacturers will be even more marked in the future, when the same distinction will prevail as now exists between the architect and the contractor. The manufacturers of structural work, in the future, will devote their energies to improvements in their tools and machinery and methods for handling material. Their engineering force will consist of mechanical experts, shop draftsmen and engineers, who, with a thorough knowledge of shop-practice, are skilled in putting the engineers' designs into convenient shape for the workshop.

Patents on structural designs and details, as well as on special shapes, have become unpopular. Designs of important structures, or those with new features, are now generally published for the benefit of the profession, and each engineer endeavors to improve upon the design of the other. Beneficial results are derived from papers, submitted to this Society, illustrating and describing new structures, as they bring out valuable discussions and thereby advance engineering knowledge.

Highway Bridges.—Highway bridges in large cities are, at the present time, generally designed by experienced engineers, and the contracts are let in accordance with legitimate practice, the material and workmanship receiving the same careful inspection and supervision as railroad bridges. These structures, however, do not represent the general run of highway bridges throughout the country. In 1852, Squire Whipple stated, in a pamphlet published by him, entitled, "The Canal Bridges, a Specimen of the Manner of Awarding Contracts by the late Canal Board," that the highway bridges over the New York State canals were let to the highest bidders and on the poorest designs submitted. The same conditions exist to some extent at the present day.

These bridges are frequently designed by incompetent or unscrupulous men, and the contracts are awarded by ignorant county officials, without the advice of a competent engineer. The merit of the design receives generally no consideration, and the contract is awarded in many cases to the one offering the poorest design and making a bid which is satisfactory to the officials, if not to the taxpayers. This condition will probably continue until, after repeated disasters, the public demands that competent engineers design and supervise the construction of county highway bridges, and that the contracts be let in accordance with legitimate practice.

Long-Span Bridges.—Long-span bridges have, of late, not only become more numerous, but their length has been gradually increased, until the long-span bridges of former years are now considered spans of moderate size only. The necessity for the great number of long-span bridges in the United States arose from the fact that many wide navigable rivers had to be bridged where the interests of navigation demanded long spans, or where they were required on account of deep and expensive foundations, or on account of other conditions determining the length of spans. There are now in existence in America about fifty railroad bridges containing simple spans of 400 ft. or more, eighteen of which exceed 500 ft., the longest one being the Ohio River Bridge at Louisville, with a span of 546 ft., completed in 1894; there are also a number of highway bridges exceeding 400 ft. span. The length of spans practicable for simple trusses has not yet been reached.

Suspension Bridges.—Suspension bridges were in use in America before any other type of iron bridges. In the earliest suspension bridges, wrought-iron links were used for the cables, and a wooden floor system was suspended from them by iron rods. The first of this kind was built by Finley, in 1796, over Jacob's Creek, on the turnpike between Uniontown and Greensburg, Fayette County, Pa. Many other bridges of the same type were built by Finley after this, the largest one being that over the Schuylkill River, at Philadelphia, Pa., of 306 ft. span built in 1809. The first wire-cable suspension bridge, was also built over the Schuylkill River, at the Falls in Philadelphia, Pa., in 1816; the span was 408 ft. This bridge had a wooden floor system and no stiffening trusses. After this, the wire-cable suspension bridge with auxiliary stiffening trusses became the favorite type for long-span highway bridges, owing to the facility of its erection. Many famous long-span bridges have been constructed of this type, such as: The bridge over the Ohio River, at Wheeling, 1,010 ft. span, built in 1855. The bridge over the Niagara River, at Lewiston, 1,040 ft. span, completed in 1850. The bridge over the Niagara River, carrying the Grand Trunk Railway and the highway, 821 ft. span, completed in 1855. This bridge has become famous as being the only wire-cable suspension bridge carrying highway as well as railroad traffic. The bridge over the Ohio River, at Cincinnati, 1,000 ft. span, completed in 1867. The bridge across the Niagara River, below the Falls, at Clifton, 1,264 ft. span, finished in 1867.

The most notable suspension bridges, however, are the Brooklyn and Williamsburg Bridges, across the East River, New York City. The Brooklyn Bridge, 1,595 ft. span, completed in 1883, was the first bridge of this kind in which steel was used for the cables, suspenders, stiffening trusses and floor system. The Williamsburg Bridge, 1,600 ft. span, completed in 1904, is the latest of the long-span suspension bridges. The proposed Manhattan Bridge, across the East River, New York City, 1,470 ft. span, is also of this type, a novel feature being the hinged steel towers.

Suspension bridges with braced cables in place of auxiliary stiffening trusses, the cables consisting of forged eye-bars, have also been successfully used for long-span bridges. The Point Bridge, over the Monongahela River, at Pittsburg, of 800 ft. span, completed in 1876, is a bridge of this kind. In locations where the appearance of the structure is one of the most important considerations, this type eventually may take the place of the cantilever for long-span railroad bridges.

Metal Arches.—Metal arches are particularly suitable for long spans in certain places. The arch combines the advantages of a graceful appearance with facility of erection without false work. Most of the earlier ones were constructed of cast iron, an important example of which is the Chestnut Street Bridge, in Philadelphia, completed in 1863. The first important steel arch was he St. Louis Bridge, over the Mississippi River, completed in 1874, consisting of three spans, the middle one, of 515 ft., being the largest. The highway bridge across the Mississippi River, at Minneapolis, having two spans of 456 ft. each, was completed in 1888. The Washington Bridge, across the Harlem River, New York City, finished in 1889, consists of two spans, each of 510 ft.

A number of arches of various types followed, the most noted of which are the two across the Niagara River, one of which, of 550 ft. span, carries the tracks of the Grand Trunk Railway and a highway, replacing the Roebling suspension bridge. It was constructed in 1897. The other replaced the Niagara Falls and Clifton Suspension Bridge in 1898. It has a span of 840 ft., and is the largest arch of any type in the world.

Cantilever Bridges.—Cantilever bridges are generally suitable for long spans only; where the length required is too great for a simple truss, or where it becomes necessary to erect without temporary supports, and the conditions are not favorable for an arch. It, perhaps more than any other kind, has been erected in places where simple trusses would have been more appropriate, and freaks of this kind may be seen in various places.

As the cantilever bridge is not as economical as a simple truss, except for spans of great length, and as simple trusses in many cases can be erected on the cantilever principle, the simple truss is generally preferable to the pure cantilever type. The Atbara Bridge, and the bridge recently erected over the Ohio River on the line of the Baltimore and Ohio Railroad at Benwood, are examples of this kind of construction.

The first cantilever railroad bridge was the Kentucky River Bridge, of three spans, each of 375 ft., completed in 1877, on the line of the Cincinnati & Southern Ry.

Many other cantilever bridges were built thereafter, such as: The Niagara River Cantilever Bridge, on the line of the Michigan Central Railroad, 470 ft. span, completed in 1883. The Frazer River Bridge, on the Canadian Pacific Railway, in 1884, 315 ft. span, and the St. John's River Bridge, in 1885, 477 ft. span. The Poughkeepsie Bridge, across the Hudson River, including a span of 523 ft., finished in 1889. The Colorado River Bridge, at Red Rock, Colo., 660 ft. span, completed in 1890, and the Memphis Bridge, with a span of 790 ft., completed in 1892.

The latest and most conspicuous cantilever bridges constructed are those over the Monongalela River, on the line of the Wabash Railroad, at Pittsburg, 812 ft. span, and at Mingo Junction, 700 ft. span, completed in 1904; also the Thebes Bridge, across the Mississippi, 671 ft. span, completed in 1905. The bridge over the East River at Blackwell's Island, now under construction, has spans of 984 and 1,182 ft., respectively. The longest cantilever bridge is that across the St. Lawrence River, at Quebec, with a span of 1,800 ft., now being built. This will make it the longest bridge in the world.

At the present rate of development of bridge building, with the materials at our command, we may see even longer spans in the near futur. It is entirely feasible to build simple trusses of 800 ft., arches and cantilevers of 2,000 ft., and wire-cable suspension bridges of 3,000 ft. spans.

Monumental Bridges.—Bridges of monumental nature have generally not received the same careful attention in this country as in Europe. There is really not much difference between public buildings and other public works of like importance. While public buildings have been designed for appearance as well as for permanency, public bridges have been notoriously neglected in both respects. Thus in large cities we see many bridges, which are far from being ornamental or sightly in appearance, situated in prominent places and in public parks in the midst of beautiful landscapes.

Such structures, which are in many cases the most prominent objects in a city, should be monumental in character, and designed on aesthetic as well as on engineering principles. Fortunately, in later years, there has been a manifest tendency toward improvement in this direction.

Any experienced bridge engineer is competent to decide upon the proper design of a structure, wherein utility and economy are the only considerations, but not if the structure requires aesthetic treatment, as engineers are generally deficient in aesthetic training. In the design of a structure of monumental character, the engineer should co-operate with a competent architect, who should be a true artist and not merely a decorator. The best results can only be obtained by a competition, such as is the usual practice with other monumental structures, the jury of selection to be composed of engineers and architects. This method was adopted in the selection of designs for the proposed Memorial Bridge and the Red Creek Bridge at Washington, and has proved very satisfactory. The Washington Bridge, in New York City, and the Cambridge Bridge, at Boston (nearly completed), are good examples of monumental city bridges.

Erection.—The erection of structures has kept pace with the rapid progress in structural engineering, requiring the institution of new methods and the development of new appliances demanding engineering skill. The increased weight of members, consequent upon the development of long spans and lofty viaducts and buildings, and the necessity of assembling the members rapidly and economically, often over treacherous streams, while carrying safely, and without interruption, the constant traffic of a railroad, have made the erection one of the most important operations connected with the construction of the various kinds of engineering structures.

The introduction of the traveler was a marked advance in the erection of structures, dispensing with a portion of the temporary supports. Later, the traveler was developed to erect viaducts and bridges of the cantilever type without the use of any temporary supports.

Until recent years the question of erection was left to the skill and judgment of practical men who had gained their knowledge and had become experts by long experience. The field operations in connection with the erection of some of the structures of recent years were of such magnitude and complicated character that it required a high order of engineering skill and experience to carry them out to a successful completion. Erection of bridges and other structures has manifestly advanced from being mere skilled labor, executed by men having only practical training, to be an important branch of engineering.

Nickel Steel.—Nickel steel has of late received special attention, and has been investigated by engineers, in relation to its usefulness as a structural material. For many years, metallurgists have experimented on the effect of the addition of special metals to steel with a view of increasing the ultimate strength and elastic limit of the steel without proportionately decreasing its ductility. So far, as a special structural steel, nickel steel is the only one which has proved satisfactory.

Nickel steels of varying carbon and nickel have been successfully used during the last fifteen years for marine and stationary engine shafting, locomotive axles, piston rods and crank pins, and a wide variety of forgings and castings for parts of machinery. Its application for the manufacture of armor plate, since 1890, is well known. It has recently been adopted, especially in this country, for gun forgings. It has been proposed for structural work before, but is now actually used for bridge construction in the eye-bars for the Blackwell's Island Cantilever Bridge across the East River, New York City, and may take an important place as a structural material for long-span bridges.

Concrete construction.—Concrete construction has been in use for many years, but is used more extensively now than formerly for foundations, piers and abutments, as well as for bridges. Marked progress was made in concrete construction when the methods of reinforcing concrete with steel were introduced. Concrete arches reinfored with steel ribs or bars, properly designed and constructed, have proved satisfactory for highway as well as railroad bridges, and are gradually superseding those of masonry construction.

Reinforced concrete is now used successfully in the construction of floors of bridges and buildings. It has also proved satisfactory for fireproofing and as a protection, to the steelwork of bridges over railroad tracks, against the corroding influence of the gases from locomotives, and will probably take a permanent place in structural work in the future.

Contracting.—Contracting has undergone a marked development to keep pace with the advances made in bridge building and structural engineering. Deep and difficult foundations for bridge piers and high buildings are more frequently required now than in former years, and while the engineer furnishes the design, it devolves upon the contractor to devise ways and means for doing the work. Many of the problems the contractor has to solve require engineering talent of the highest order, and some of the contractors' engineers are men of exceptional ability and of high standing in the profession.

THE USE OF SUPERHEATED STEAM ON LOCOMOTIVES.*

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HISTORY.

The use of superheated steam has rather a peculiar history: unlike the turbine, which lay neglected, with its possibilities unknown, through the years in which the reciprocating engine gradually attained its present state of perfection, superheating was employed and proved its value when the steam engine had already left the experimental stage, when reliable operation had become established, and economy was regarded as a matter of importance. After demonstrating the advantages that could be gained by its use, it was gradually abandoned by the large majority of engineers, and not again resorted to until successive stages of increasing pressure, ordinary multiple compounding, jacketing and refined designing, had been brought to their greatest perfection. When its reintroduction took place, its progress was slow, and

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