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AN ADDRESS

(At the lecture-meeting held by the Civil Eng. Soc. on May 14, 1929)

By Prof. William Hubert Burr.

In the preparation of a paper for a technical society whose members are experienced engineers of attainments and prominence, there are found some serious difficulties in the endeavour to meet the requirements of such an audience. In fact if a speaker were not confident of being among old and lenient friends the situation would inevitably indicate rashness on his part. Fortunately for me I have had and still have many warm friends among the prominent civil engineers of Japan, many of whom are the graduates of the Tokyo University, which it was once my opportunity to serve, but adverse personal circumstances at that time, most regretfully prevented the realization of such an honour. My many Japanese friendships, in which I have always enjoyed much happiness, have given me a deeply cherished hope to visit Japan and enjoy for a short time at least the personal association of my old student friends, and after many years I have at last realized that hope, although I cannot fail to be touched with a little sadness in that some of my oldest student friends "have passed on" and are not here to greet me.

Inasmuch as we are here as a group of friends I have concluded to touch briefly, and briefly only, on some phases of our common profession relating both to the past and the present, in order that we may have a little better view of what has been accomplished in our profession within the experience of some of us at least.

When I was a student at the Rensselaer Polytechnic Institute, Troy, N. Y., between the years 1868 and 1872, neither I nor any other student associated with me, ever heard the words "Plain and reinforced" concrete or Portland cement or "Natural Cement" mentioned in a class or lecture room at Troy. To me that, now, seems incredible, but it is literally true. The French words "coignet-beton" were, I think, mentioned on a few special occasions but I doubt if a single student who heard them knew what they meant. In other words a great special field of work in plain and reinforced concrete, with Portland cement as cementing material had not then been born, so to speak. Those of us who purchased Trautwines "Pocket Book" published in 1871 got from that technical book some practical ideas about Portland cement which had a few years before been brought into notice by the eminent English engineer John Grant. Within six months after my graduation I was brought summarily face to face with the American products of Howe's Cave and "Rosendale Natural Cements", and from that time until this, I believe, I have scarcely been free from participation in the construction of either plain or reinforced concrete work, and sometimes in vast quantities.

Comparatively little Portland cement was ever imported into the United States except for a few special works of little magnitude, at any time, but the natural product Rosendale cement and some others of similar quality began to be used quite widely until about 1890 when the early efforts were made to produce a high quality of Portland cement in Pennsylvania. From that time on domestic Portland cement began to come into general use, until now it is the basis of enormous quantities of the highest class of plain and reinforced concrete construction, and in the greatest variety of structural work which the engineer designs and constructs.

A great mass of what may be called, without serious error, hyper-refined experimental work has been done to determine best mixtures and proportions of cement, sand, gravel or broken stone, relative amounts of coarse ingredients, water, "slump", rates of setting, etc., etc., but there are no rules of procedure which can safely displace the trained judgment of an experienced engineer in his consideration of the varying character of the materials necessarily used under differing conditions in different localities and for different purposes, and for waterproofing under high heads. The latter includes such judicious selection and use of available materials as will reduce the total voids in the fine and coarse aggregates to the least possible, whatever the "slump" may be or whatever meticulous rules may be prescribed.

The proper handling of fresh mixed concrete to be deposited under water, especially where strong currents exist remains even now a real problem despite the improved steel bottom dumping buckets holding two or three cubic yards usually employed for this purpose. The imperative requirement is either a temporary or permanent enclosure, properly shaped for the finished work and fitting the hard bottom to be covered, within which the water has absolutely no current (i. e. it has no motion) and within which the concrete may be deposited in approximately uniform layers to any desired elevation. After the deposition under water is completed, the enclosure may be pumped dry enabling the work to be finished in air, first thoroughly cleaning off the laitance accumulated on the firm concrete. It is worth repeating that the fundamental requisite is the suppressing of all currents in the enclosure before depositing any concrete under water, otherwise there can be no confidence in the results. I have used this process for many years without a failure, the last work of the kind being the foundations of one of the large piers of the Carquinez Bridge near San Francisco, Cal., with a depth of water a little over 100 feet. A rich concrete, not less so than one cement, two sand, four gravel or broken stone should be used.

The practice of handling large masses of fresh concrete, distinctly "wet", moved by gravity in inclined chutes, inevitably "ravels" the concrete even if the slopes of the chutes are not steep, but its use may be pardoned under proper selection of the coarse aggregate and mild slopes of the chutes. In some large works much remixing has had to be done at the point of deposition in order to prevent "economy" becoming "cheapness". This method is popular because of its low cost, but the conveyor belt has been successfully used in placing a great mass of concrete in the foundation of the Manhattan tower of the Hudson River suspension bridge. Excellent quality and satisfactory cost were attained.

Turning to another fiield of engineering construction, iron and steel bridge construction may be said to have had existence from about 1845 to 1850, when the small bridges were first built across the Erie Canal in the State of New York, by Squire Whipple. In fact he may properly be called the father of that field of construction.

The full fledged construction of wrought iron bridges began to be realized in about 1865 to 1870. In 1871 the Phoenix Bridge Company built the New York Central Railroad bridge across the Hudson River, at Albany, New York.

The tensile members of the lower chords of the structure were circular rods, with an eye or head bored to the diameter of the pin forged at each end. These roundl ower chord rods were the progenitors of the first wrought iron eye bar used in such great numbers in American bridge practice from approximately 1870 to 1900. In the latter part of this period, however, low or medium carbon steel was used in place of wrought iron, necessitating the annealing of the bars as upset and formed in a suitable die. This eye bar made the pin connected truss bridges possible and they were used in great numbers both for railroads and highways throughout the United States, and many of them are still in use, although the steel eye bar is made in small numbers only at the present time.

Practically all of the latter steel eye bars are produced by the American Bridge Company which constitutes the Bridge Department of the United States Steel Corporation. The special heat treatment which that company has developed produces an ultimate resistance of the steel used in the bar far higher than any metal of a similar kind yet produced. The grade of steel used for this purpose is the ordinary mild carbon steel subjected to a suitable heat treatment determined by actual experiment with full size bars.

The all riveted wrought iron and steel trusses extensively used at the present time in the United States as well as in other countries, has always been a sharp competitor for the pin connected bridge, either for railroad or other purposes. This competition had its active period from about 1870 to 1900 and finally gained for the all riveted structures the first position of excellence in the railroad bridges of the United States. Pin bridge construction for railroad purposes is likely to disappear in a comparatively short time.

Experience has shown that in the railroad pin bridges of the United States, rapidly moving trains cause an intense vibratory motion at all pin points sufficient to produce serious wear between pins and the interior surfaces of pin holes, thus cutting channels into the pins or eye bar heads to depths of 5/8″ or more in some cases. These results have been shown in many structures, both by removal of pin connected bridges for replacement and in other cases by careful examination of structures in actual use. This characteristic and serious defect of pin connected structures has been demonstrated in my own experience as well as in other instances of bridge removals by other engineers of experience in bridge practice.

In passing over the lines of the Imperial Japanese Railway system, between Kobe and Tokyo, I observed that practically all iron or steel bridges on that line were of the all riveted type, showing good engineering judgment in the original selection of the type to be built.

The violent vibratory motions at pin points, under the passage of rapidly moving trains, especially if the latter have large variations in intensity of loading, induce much graver complications than ordinarily supposed. Not infrequently in removing old pin connected bridges, grooves in pins and eye bar heads are not only found worn to weakening depths, but it becomes necessary to sever pins and eye bar heads with a suitable torch by burning and fusing the iron or steel, simply uncoupling the joints being impossible.

This distinctive vibratory influence in the case of pin joints does not lend itself easily to analytic determination, but the results of actual observation are confirmed by the results of analysis so far as it is practicable to carry that analysis. The latter considerations are specially applicable to suspension bridge cable eye bars, where the motions of the latter on pins is highly objectionable since the vibratory motions render it essentially impossible to protect pins and the interior surfaces of pin holes in the eye bar heads effectively against serious corrosion, and, hence, to insure a long life to the eye bar cable. This particular hazard of the eye bar joint and the eye bar cable has only lately been recognized, but that recognition is now clear and well based and must be given title to clear recognition hereafter.

There is probably no special field of bridge construction in which there has been greater development than in that of the metal from which the wire for the main cables of long span suspension bridges is drawn. The wrought iron wire used in the cables of the stiffened suspension bridge over the Niagara Gorge, and built by John A. Roebling about 1858, had an ultimate resistance of about 60 000 lbs. per sq. inch, and about the same quality of material was used in 1884-88 by the same Chief Engineer, Mr. John A. Roebling, in the construction of the Brooklyn bridge across the East River at New York City.

At the present time the Port of New York Authority is constructing a great stiffened suspension bridge across the Hudson River at 178th Street, near the North end of Manhattan Island, designed to carry all classes of traffic now found on any of the principal streets of New York City, including street cars, buses of all classes, automobiles, horse vehicles and foot traffic, etc., etc. The main span is 3 500 ft. and the clear height under the structure is over 200 feet. The steel work of the two towers is about 600 feet high. The wire cables are four in number and each is 36 inches in diameter; they hang in two vertical planes, one over another in each such plane. The steel wires have an ultimate resistance of 220 000 lbs. per square inch, or about 3¾ the ultimate of the wire used in the Niagara and Brooklyn bridges. The quality of the steel used in other parts of the structure than the cables exhibit about the same proportionate advances in all physical qualities as those members.

The type of cable for a long span suspension bridge is of prime importance. It must be so designed and constructed that it may offer the greatest possible resistance to corrosion in all its parts. It should, therefore, be so formed that water or salt mists, even, cannot find their way into the interior of the cable masses, or in such a way as to contain practically no interior voids accessible to mists or actual rainfall, otherwise corrosion will take place in such voids although they may not be accessible to direct rainfall. For the same reasons all interior cavities should be accessible to the paint brush. Again all exposed parts should be of such a character as to give full and easy access to inspection. The circular cable laid up with parallel wires so as to produce a circular cross section meets all of these requirements in a most effective manner, and that is the reason why cables with circular section laid up with parallel wires are predominant in all the great long span stiffened suspension bridges. The strands of such cables are made up with parallel wires held together with circumferential wire ties and laid parallel to each other in assembling a cable in position. These strands are in hexagonal position, so to speak, in the cable cross section. After the wires and strands are laid parallel to each other, the whole mass of each cable is compressed by a suitable machine equipped with sufficient power to squeeze the entire cable into a uniform circular section at all points. The cable is then wound tightly traversely to its diameter by wire about the same diameter as the single wires of the main cable. This tightly wound sheath of at least one sheathing course is then heavily painted after completion, and it may be painted at any time in the future when a proper maintenance requires it. In fact each individual strand may be painted before it is laid in its permanent place, if so desired, but this is not generally required. As the cable is laid up in place in the manner indicated, it is obvious that the exterior exposed surface is the least possible with a given amount of metal in the single wires. Experience in the maintenance of this type of cable has demonstrated that it is entirely feasible to protect effectively the mass of metal in it against any possible corrosion and as the tension in each single wire is tested to make its stress, due to its own weight, precisely the same as that in any single wire, it is safe and proper to assume that the distribution of tensile stress throughout the mass of any such cable is practically if not exactly uniform. Present methods of erecting or putting in place these great suspension bridge cables have been demonstrated to be effective in securing all the desired results. It is therefore, unnecessary and unwise to experiment on such a huge scale with methods and materials, some of which, at least, have been shown to be ineffective, or worse, by actual experience.

The great length of span of the Hudson River bridge and the extraordinary variety and weight of moving load gives the dead load or own weight of the structure unusual magnitude. Indeed the great dead load constitutes or creates the actual stiffening element or quality of the bridge.

That part of the structure which is carried directly to the cables by the suspension rods forms a distributing steel framework for the moving load, but the latter is so much less perlinear foot of span than the dead load per foot, that it causes a relatively small distortion of the cables. The "stiffening trusses", therefore, have light functions consisting chiefly in distributing the moving load over the floor of the bridge.

With the heavy moving loads, moving simultaneously in both directions, there will be comparatively rapid changes in position of large and varying portions of it, or them, causing distortion of the cables by variations in their angles of inclination sufficient in magnitude to be easily computable. These changes in inclination of the cables at various points indicate in the case of eye bar cables measurable small motions around the pins or corresponding secondary stresses also easily computed. This condition is what may be called a dynamic condition of the cables. It can be shown that the eye bars of an eye bar cable will actually turn with small motions around the pins in the constantly varying efforts of the cable to adjust itself to the incessantly varying moving loads on the bridge, but without equilibrium between the two ever being attainable. This dynamic relation between pins and eye bars renders it impossible to make effective protection against corrosion around the pins and pin holes of an eye bar cable in such a great structure as that now building across the Hudson River at New York. Nor would it be possible for inspectors to crawl in and among the great banks of eye bars numbering and to ascertain the existence or the progress of corrosion due to salt water mists and rain driven into all the interior parts of such a cable by winds and air currents.

These observations, sketched in an imperfect and skeleton manner, taken in connection with the results of corrosion and channel cuttings by eye bar heads in pins of ordinary pin connected bridges, are sufficiently conclusive to indicate that eye bar cables are not rationally or safely adapted to the requirements of long span stiffened suspension bridges. The bidding of contractors for this work fortunately showed the wire cable to be more economical than its competitor the eye bar cable.

As great as have been the advances in steel bridge construction in the past twenty-five years, there is no reason to believe that even small recessions in quality of material or shop processes are to be looked for in the near future. The excellence of shop work in the construction of the great towers of the Hudson River bridge has been pushed by the contractors quite beyond that reached in the same class of work heretofore, and similar observations can fairly be made regarding other parts of the same work than the steel construction, as in the case of the foundations of the New Jersey tower where an open coffer dam was successfully used with economical results in depths of water over seventy feet without the aid of compressed air.

It was my privilege and pleasure to inspect both the old and the new iron and steel bridges now spanning the Sumida River within the limits of the City of Tokyo, and I have no hesitation in stating that they were originally designed and constructed in accordance with the best engineering principles known at the dates of construction, and the same observation can be made of the later foundation structures.

Again, the plans of improvement of the Park areas along the borders of the river have been developed in accordance with the governing features of similar work in such modern cities as New York and Boston in the United

States, especially in the use of substantial granite masonry where parmanent structures of masonry are required.

It gives me much pleasure to make these comments on some of the large public works of the City of Tokyo, including the subway under construction, for the plans of these great city improvements impress me as wise and effective in being well considered with their actual execution spread over a sufficient future period to make the financial burden reasonable and the development of their main features mature and pleasing to the future great city.

The End.

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(The following is the address of thanks delivered by the President to Professor Burr.)

Let me take this opportunity, representing the members of the Civil Engineering Society, to thank Professor Burr, for the interesting lecture he has kindly delivered.

It is not necessary to speak of the Professor's engineering achievements and investigations, which are so highly esteemed all over the world, but I can not stop without speaking of his service to this country.

The late Doctors Matsumoto Soichiro, Haraguchi Kaname, Hirai Seijiro, Shiraishi Naoji, Hiroi Isamu who stood in leading and prominent positions of our engineering and educational society were educated by Professor Burr; and many engineers who visited the United States got instruction, advice, and conveniences to see and study engineering works in the States and abroad by the Professor's courtesy; moreover still many engineers learned from and interested themselves in books and papers by the Professor.

We owe a great deal of our engineering progress to Professor Burr, and on this occasion we wish to show and express a token of gratitude.

Amongst other engineering works Professor Burr taught us how to build beautiful and substantial bridges connecting two banks, standing against storms and floods, and opening an uninterrupted line of communication.

The Pacific Ocean originated in peace and tranquillily, Professor Burr also teaches people on both sides of this water, to make substantial and peaceful lines of communication in all kinds of weather.

At the end, I again thank him for the interesting address, such as we seldom have the pleasure of listening to.

S. Tanabe, President
The Civil Engineering Society, Tokyo,
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