The President (Prof. W. C. Kernot) said he was glad they had Prof. Warren present, who knew more about this system than he (the President) did. He had simply brought down some drawings and particulars prepared by those who had had some experience of it. He briefly explained that the principle of the Monier-system of construction was that it was a combination of iron and concrete. The inventor thought that the insertion in the concrete of certain bars or rods of iron would greatly increase the strength of the mass and without adding to the bulk or weight of the structure. It was alleged by the advocate of the system that the iron and concrete worked remarkably well together. The expansion or contraction under varying temperatures of the iron agreed with that of the concrete. The iron took up its full share of any tension that existed so that all parts of both materials were fairly utilized. The adhesion of cement to iron was well known. In the case of steamers where Portland cement was used experience showed that it gave an extraordinary durability to iron as compared with iron in the parts exposed to the ordinary action of the atmosphere. Four points of interest in connection with the system were:—(1) The approximate agreement between the materials as to expansion and contraction under varying temperatures; (2) The relation between the elasticities of the materials under varying stresses; (3) The close and strong adhesion of the two materials together; and (4) Consequent on that, the preservation of the iron, all of which pointed to the eminent suitability of the system for many purposes. The iron bars, or rods, should be inserted at places where tensile stress was likely to be experienced. It was applied sometimes in the form of beams and sometimes as arches. Experiments made by the late Professor Bauschinger (a leading authority in Germany) with two plates of equal thickness—one consisting of a mass containing one part of Portland cement to three of sand, and the other containing these materials, in the same proportions, with a lattice of iron rods bedded into the plate—gave a result equivalent to twelve times a greater strength in the case of the latter plate. Other tests made gave results in the same ratio. The same authority was quoted as stating that pipes made by this system were six times stronger than earthenware pipes as made in Germany, although he (the speaker) doubted whether this ratio would apply to the really excellent pipes turned out by Melbourne firms for our sewer system. The Monier system was submitted by the holders of the patent as an alternative to the ordinary system of construction for the building of sewer aqueducts in Sydney, and, as it was very novel, strict and exact
tests were made before it was decided to use it. These tests were certainly remarkable. Two arches 20' 6" span, 1' 10' 1/4 rise, 3/4 thick at the crown, 5" at the springing, and made of 3 to 1 cement mortar, were loaded with bags of cement and pig iron. The greatest weight necessary for them to carry was 112 lb. to the sq. ft., and as they stood a strain of twelve times this without any appreciable deflection the tests were considered tamely satisfactory. Experiments had shown that cement concrete would resist the action of fire in a very remarkable degree. It could be made impermeable to water by a thin surface coating of cement mortar of a richer description. (Two books containing a number of drawings showing details of the system, and some drawings of works in which it had been practically applied, were examined by the members present.)

Professor Warren said that the President had explained the subject of the Monier System so thoroughly that but little was left for him to say. The drawings before the members, and illustrating the examples which existed in Sydney, were well shown, but the structures in reality looked very fine. In the Monier System the proportion was one of cement to three of sand always for use with the iron. It was really a good mortar. It did not do to have ordinary concrete, because that adhesion which was so essential might possibly not be obtained. In the building of arches it was necessary to have the arch completed in one day so as to avoid the possibility of a dry joint, and to do that a great many men were required on the work, the object being to produce a homogeneous mass of composition adhering to the iron mesh work embedded within it. (He drew the attention of members to several matters of interest shown on the various plans exhibited.) The late Professor Bauschinger, of Munich, in his experiments had obtained 350 lb. to the square inch adhesion for cement mortar. He (Professor Warren) had made experiments with the same material, but he did not get quite so much. This he attributed to the fact that his specimens were not made properly. He did not think his results were altogether accurate for this reason, and he had no doubt that the results given by Professor Bauschinger were quite correct. The transactions of the American Society of Civil Engineers of April, 1894, gave the best idea of the Monier system. It was brought into use by a man in France named Monier for making pots for tree plants. It has since been largely used. He saw in Vienna one or two bridges over the Danube which were made on this system and they looked very well indeed. Arches built on the Monier plan came out very much better than those of ordinary concrete. The "Melan" was another system largely used in bridges and had been applied in America and Germany. It consisted of rolled steel or built girders surrounded by concrete, the girders are spaced from 3 to 6 feet apart with the concrete between, as well as above and below the girders. With regard to the strength of the "Monier" beams one would get a better notion of it by considering the strength of an ordinary mortar beam and that of a beam of similar dimensions with a mesh of iron. The compressive strength of the cement mortar would indicate the load that could be put on a beam and sufficient area of iron provided to render the tensile resistance equal to it. Good mortar would stand 2000 lb. per square inch. That was a fair
and reasonable thing, and it could be got in a mortar about 28 days old. Professor Bauschinger states that by the adoption of the Monier System the strength is increased in the proportion of 12 to 1, but in designing if an allowance of 10 to 1 be made safety will be attained, and the strength of a beam is practically increased ten times. If Professor Bauschinger's twelve times be taken, it is requisite to decide how much iron to add to the tension flange; the beam is worked out in the ordinary way, and the area of the iron is simply calculated on the assumption that sufficient area must be introduced in order to make it equal to the compressive strength of the mortar. It is worked out easily that way. As to the durability of the system, he said cement mortar made the best material for preserving iron. Iron that was often rusty became clean when embedded in cement mortar. In the North Sydney Suspension Bridge the cables were embedded in cement mortar of 3 to 1. If ever the bridge should be used it would probably be necessary to excavate about 6′ to see how the cable would look. It had been there about four years, and that would be one test of the durability of steel when embedded in mortar. Of other systems there was one known as "Wünch System," with a frame of angle or tee bars is embedded in concrete. It did not differ much from the "Melan," but the latter seemed to be preferred for small spans. In another system twisted iron was used; this was due to a false impression that greater rigidity could be got from the iron twisted within the elastic limits of the material. He had some special apparatus for determining the elastic co-efficients of brittle materials, and he proposed to make some experiments on the elastic co-efficients of cement mortar and concrete with a view to the design of composite iron, steel, mortar, and concrete structures. In reply to Mr. Rennick, he said that it was not necessary for the iron to be perfectly clean when used. He thought from his experience that if the iron could be kept absolutely air-tight no further rusting would take place, but if the air got to it a little scale of rust might spread all over the plate. He had seen it keep good for many years when it was absolutely water-tight. He was inclined to think that cement would adhere better to clean iron. Americans were now generally using the system for fire-proof structures, and it was found to be very useful for large spans.

The President said that, possibly, if any of the iron were left exposed water might get in and be conducted over a large surface, and in such case the cement would really do harm by hiding the depreciation which would be going on, but the system provided for the iron being completely covered so that no water could get in from outside.

Mr. Fyfe confirmed the fact that cement was a splendid preservative for iron by his experience with iron vessels; but he had experience in one case of a steamer where water had got between the cement and plates and rusted a hole in the steamer's bottom—but in that case the want of adhesion was due to the iron having been painted before the cement was applied.

A vote of thanks was accorded to Professor Wargen for his attendance and for the instructive information he had given to the meeting.
BRIDGE AT THE NORTH WEST GERMAN INDUSTRIAL EXHIBITION, BREMEN.
OVER HEAD BRIDGE AT MATZLEINDORF STATION, NEAR VIENNA.
Bridge over Hungarian N.E. Railway
DISCUSSION ON THE MONIER SYSTEM OF CONSTRUCTION.

Prof. Kernot again briefly explained the system for the benefit of members who were not present when the drawings, &c. were not present when the drawings, etc. were first shown, and introduced to the meeting Mr. Gummow, who in conjunction with Mr. Carter, had brought the Monier system into use in Sydney.

Mr. J. T. N. Anderson asked if this material could be used for pipes in Hydraulic Works, where the concrete is entirely in tension? He had good reason to know from experience that cement with iron introduced had a very considerable tenacity. They were all aware of the trouble with iron pipes,—they had not such a long life as one would like, and consequently in making wrought iron pipes for pumping schemes, &c., provision had to be made for a large amount of deterioration, reckoning the life of the structure to be slight. Many attempts had been made to line W.I. pipes with concrete. Other schemes had been tried to get pipes with the lightness of the W.I. pipe, and at the same time of greater durability than those ordinarily used in waterworks construction. A pipe was shown on one of the drawings as being laid continuously. It was of considerable length and about 3' or 4' in diameter. If this were correct, what pressure could they safely be made to carry, and how did they compare with the price of W.I. or steel pipes for similar work?

Prof. Kernot—In the near future there is the great Coolgardie scheme for water supply. The present proposal was a pipe conduit 30' in diameter, 300 miles in length, portions of which, it is said, are to be laid through ground of a saline character, where the life of iron pipes is precarious. Is there not a field for this system of construction there. This system is worth giving some attention to.

Mr. Gummow in reply to Mr. Anderson said the question of the pressure that could be put on a pipe on the Monier system was not taken into consideration. It was not necessary to look into the internal pressure for the simple reason that concrete would not stand more than 50' or 60' head of water, as proved by experiment. At home the Monier pipes were not used, except under a very low head of water, e.g. culverts, where they might get a pressure of 8' or 10'. As to external pressure, they had made no experiments themselves. A pipe 3' long 1 1/2' thick would stand 15cwt. per sq. foot. For a culvert 16' x 11' 3'', 3 3/4' at the crown by 6'' near the haunches, the calculated safe load was 1840lbs. to the square foot.

The question of internal pressure with regard to culverts or pipes was never gone into on account of the porosity of the material itself.

Prof. Kernot—Re the Coolgardie Scheme. In some portions the pressure would be very low, but at other parts it might be as high as 400'
Mr. Gummow:—Re Prof. Warren's remarks about the North Sydney Suspension Bridge in which he had stated that the work was carried out with 3 to 1 compo. They had found that this material expanded equally with iron. The arch had risen 3/4" from a hot day to a cold night. The carrier was built of a mixture 21\frac{1}{3} parts blue stone, 1\frac{1}{3} sand and 1 of cement by that means they got a very rich mortar, with small stone embedded. That mixture was very hardy. The question of impermeability was of greater moment than the strength. The greatest compression which had occurred was 250 to 300 lbs per sq. inch. At home up to 700 lbs per sq. inch. compressive strain was allowed. Their system was rather severely criticised at first by the New South Wales Government, on account of the lightness of the structures they placed before them. The piers themselves resting on the arches were an eyesore to many people at the time. It was stated that the arch would be crushed at that particular point and break through.

The small or "Jack" arches thrown over from one little pier to the other one 3" thick. He had been asked why they did not put on a side load instead of a full load in the structure under discussion. It would be unfair to test a structure for use for which it had not been designed. For the main piers expansion joints were put in the carrier itself. The object of that was that as the 80' arch rose and fell with the varying temperatures, the carrier would not crack. In Europe the expansion joints were not used.

On the top of the carrier plates were put on, which were made on the grounds and put into position. One of these was 7' or 8' square, and only 4" thick. 15cwt was put on that as a centre load, and it stood well. The iron seemed to bind it well together. He would like this subject criticised. It should be supported as a sound engineering work. Other floors, walls, &c., had been put up but this bridge was the largest work executed in the colonies on the Monier System.

Mr. A. G. Shaw.—Did you try the experiment of putting a load on and taking it off rapidly a great number of times?

Mr. Gummow.—The only experiment was with the 26' arch. Fifty men were put on as closely as they could pack them and made to jump to time. There was a deflection of 1-20th of an inch. In reply to the Chairman he said they were building a railway bridge in N.S.W. 40' span, 8' at the crown to 10' at the bottom.

Prof. Kernot.—Take the case of the brick bridge at Northcote, where there were 8 rings forming an arch of 60' span, 15' rise. If such a bridge were built on the Monier system, what proportions do you think you would adopt?

Mr. Gummow.—In this case the rise is great. He would put in 6" at the crown, and say 10" or 12" at the bottom. He would not use the jack arches, but would fill it in solid.

Prof. Kernot.—The rise might be reduced if you wished it.

Mr. Gummow.—If the rise were reduced they would have it thinner at the crown and slightly less at the bottom. In calculating the curve of the arch they always allowed that the centre line of pressure came into the
cross-section of the arch at such a time when the worst class of loading was on, such as a steam roller.

Mr. Stone enquired if there was any risk of cracks and of the water finding its way in?

Mr. Gummow, in reply, read the following extract from a paper read by Mr. W. Baltzer before the Engineering Association of N.S.W. on 9th Sept., 1897:

"The first hair-cracks occurred in the rubble under a load of 56.5 tons, in the brick arch under 42.02 tons, in the concrete arch under 63.3 tons, and in the Monier arch under 78.5 tons. The rubble arch collapsed under 74 tons, the brick arch under 67.5 tons, the concrete arch under 83.3 tons, and the Monier arch under 146.1 tons. Making a comparison of these figures, it will be seen that the breaking load of these arches compared with the Monier arch (the latter taken as 100) is:—For rubble, 51; for brick, 46; for concrete, 57; and for Monier, 100. And comparing the tensile strengths of the materials used, I find that the tensile strains which caused the first hair-cracks in the different sections varied:—In the rubble arch from 95 to 133 lbs. per sq. in.; in the brick arch from 58 to 109 lbs. per sq. in.; in the concrete arch from 205 to 369 lbs. per sq. in.; in the Monier arch from 522 to 712 lbs. per sq. in.; thus demonstrating the great tensile strength and homogeneity of the Monier material.

The tensile strain at the different cross-sections of the arch when the first hair cracks appeared were from 522 to 712 lbs. per square inch, and as the tensile strength of the concrete alone was only 284 lbs. it is clear that the iron sections embedded and forming with the concrete a homogeneous mass, increased the strength of the body to double that of the concrete, thus showing what an important factor the iron insertions play in the arch. The co-efficient of elasticity of the body, as derived from the deflection noted, showed a gradual decrease under increased loading, but it was found that this decrease was of no consequence, as the arch still acted as an elastic body on account of the iron insertions being still perfectly elastic. The Ratio of the distribution of the stresses through the concrete and iron, under an assumption of a constant co-efficient of elasticity for the iron insertions, varied from 1 to 15 to 1 to 70, as the load was increased to 78.5 tons, at which stage hair cracks appeared, showing that the elastic limit of the homogeneous material had been exceeded. The tensile strain on the iron at that stage amounted to 8.2 tons at F., and 5.1 and 5.3 tons at points E and D respectively, showing that the iron was still perfectly elastic, though the elastic limit on the arch had been overcome, thus showing a very marked increase in the safety of such an arch is obtained by the insertion of iron rods, when compared with an arch of concrete alone, so that greater stresses can be allowed on the sectional area of a Monier construction than would be admissible in stone, brick, or concrete." They never allowed a bridge to be calculated so high as to risk getting a hair crack. If a hair crack did occur, there was no danger of a bridge falling.

Professor Kernot did not think there was much danger in these spaces. Assuming that a small crack did occur, a free access of water to the iron
DISCUSSION ON THE MONIER SYSTEM.

would be speedily stopped. As a rule iron structures did not suffer very much from water getting in to them. Since last meeting he had been examining a structure which had been exposed to all weathers for 40 years and it had not suffered very much from the rain. Corrosion of iron seemed to be very small, provided that it was not exposed to some specially corrosive material. Ordinary rain water did not affect it much. The iron in the tramway did not suffer from corrosion to any appreciable extent.

Mr. Johns: How does the cost of the brick and the concrete compare with that of the Monier system?

Mr. Gummow: It varies. In the case of the 60' span bridge, in Germany, the concrete and Monier cost the same. Bricks cost a little less, and the rubble was the cheapest of the lot. In arch construction in the colonies, as compared with brick, the saving is 33 per cent. The cost of the material is 50 per cent. more, but only 4/3 to 1/3 the quantity is used. The cost of the pipes varies. For pipes 22' to 2' the Monier system was 15 per cent. cheaper. No earthenware pipes were made larger than that in New South Wales. Three feet Monier pipes can be delivered in the city for 11s. to 12s. a foot, and 6' pipes at 30s. a foot.

Mr. Champion said, as far as he could learn from the information submitted, this system of construction was a remarkable one. He was glad to see Mr. Gummow present.

Professor Kernot hoped soon to see a typical example of the Monier system of construction in the colony of Victoria. There was no question about its success. It had been tried on the continent of Europe and also largely in New South Wales. There was saving in the cost of the structure itself, and a great difference in the weight. The appearance of lightness was—to say the least of it—worth something. The arbitrator in the Parke's case, after seeing some aqueducts of the old type, said "the Monier one was like a graceful buggy and the other looked like a bullock dray" compared with it.
Library Digitised Collections

Author/s: Kernot, William Charles

Title: The Monier-system of construction (Paper & Discussion)

Date: 1900

Persistent Link: http://hdl.handle.net/11343/24270

File Description: The Monier-system of construction (Paper & Discussion)