29th JUNE, 1911.

DISCUSSION.

Mr. Reeks, in opening the discussion, said that the paper read by Professor Warren was highly interesting, and he could only echo what Mr. Shirra had said, viz., that we should look upon Professor Warren's work as the timber merchants' Bible. They should look upon it with still greater interest when he had finished, and he hoped, put before this Association, the series of experiments he is carrying out now. He was afraid that we are all apt to look at things from a selfish point of view. The particular point he would like to mention in connection with the paper is that under the most general conditions timber is not put to torsional stresses, but those who have to do with steamers know that it is a very important point indeed. In the ferry boats, for instance, the rudder stocks are something like 20 to 23 feet long. If, in the course of his investigations, Professor Warren can give us the full information on the torsion resisting powers of some of our principal timbers, it would be very valuable indeed to certain of us. Under ordinary circumstances we go very largely on the rule of thumb. We say, "Oh, yes, there is nothing in the world like iron bark," and we take great care to see that our rudder stocks are big enough. But that is not at all a satisfactory way of doing it. We should know something more about all the particular features of our timbers, so that we may be prepared to determine our requirements reasonably. There were quite a number of members present wishing to ask Professor Warren questions, so he would not say any more.

The President, Mr. Julius, said that he thought they ought to enter into discussion more readily. The matter that Professor Warren had put before them was of such vital interest to them as engineers that it very well warranted full discussion. He had a few questions to ask the Professor, and to assist the discussion he would put them now. With regard to the shearing tests, which had been carried out in several ways, the Author made reference in his paper to the fact that he differed from the methods that were adopted by other experimenters in applying the shear load to the specimens in order to eliminate double shear. It had always seemed to the speaker, from an examination of the various appliances that have been used in conducting such tests, that to eliminate double shear is extremely difficult without introducing other troubles. In adopting the appliances that Professor Warren used for developing single shear, it seems that one is very apt to get erroneous results. With the "dog" that is used for applying the load, and owing to the fact that the majority of our timbers do not shear on an even plane, results in an over-high shearing value, as the load is supported by a number of fibres, or portions of the timber in compression or tension. A number of the diagrams that the Professor showed us seem to bear out that contention. The contour of the failure was a very crooked surface, and in applying the load the dog must have rested on the high points of that surface and must give very inaccurate results, since the compression strength of our timbers is usually very much greater than their shearing strength. Some years ago, on behalf of one of the Australian State Governments, the speaker carried out a number of tests, and he adopted similar appliances to those previously used by Professor Warren, although not altogether like the apparatus described. He also adopted a method that was due to Professor Johnson, in the United States, in which the specimen came under double shear, and he invariably found more uniform results were obtained throughout with this latter apparatus than with the single shear methods. He also found that the single shear frequently gave results so high that they could not possibly represent the shearing strength of the timber. In examining the failures he came to the conclusion that a number of the fibres were subject to tensile stresses, and gave inaccurate records in the shearing tests. For that reason he adopted the double shears method, and very uniform and, he believed, accurate results were got. He should like to hear Professor Warren's views more fully on that point.

Another set of tests that particularly drew his attention were the abrasion tests carried out by means of the sand blast. It seemed to him that those tests were of an extremely valuable nature. Our timbers here are eminently fitted for street blocking, and the abrasion of the blocking is one of the main factors in determining its efficiency. It is extremely difficult to apply any tests that will satisfactorily determine the resistance of various timbers to abrasion. He thought the method adopted by Professor Warren to be as nearly complete as possible in the reproduction of the conditions to which the blocks are subjected in practice. He should very much like to see the tests carried further. There is a number of timbers which Professor Warren used in his tests, and quantity of data might be obtained as to their behaviour under different conditions, with varying percentages of moisture; such moisture, in the first place, being the ordinary sap in the timber. He would suggest treating green and seasoned samples, and also very wet samples. There is no doubt that if one examines the surface of blocking in traffic ways a very peculiar set of conditions obtain where the road is subjected to a great deal of moisture. There is also a number of processes for the treatment of timber, with one of which he had been associated; and he had at the present time a number of blocks of various timbers which had been subjected to this process, and which he ventured to ask the Professor to subject to his abrasion test, because he thought it was of much importance.

Another test that was new to him, when applied to timber, was that of torsion; and the results obtained, particularly the nature of the fractures, lead one to believe that although at first sight the test does not appear to be one of surface failure, the work would shed considerable light generally on the behaviour of timber under various forms of load. He was aware—probably more than anybody here, except Professor Warren—of the work involved in the testing of timber, owing to the fact that whilst in the case of metals it is necessary to deal with only a few samples, it is desirable to test hundreds of samples of wood. He knew the value of the work done by Professor Warren in these experiments, and it would be of the greatest value if he carried certain of those tests, notably the abrasion tests, the test under impact, and the torsion tests, further.

One other point he would like to mention. In examining the records shown and described by the Professor there is a very wide discrepancy between the results obtained from the various samples, not merely at different percentages of moisture, which one expects and knows one must get, but also between the samples possessing the same percentage of moisture. So much did these results differ in many cases, as the Professor pointed out, that the speaker was satisfied that we do not know enough about the specimens to lay down the law. It had struck him that possibly the relatively limited number of samples available made it impracticable to discard samples and specimens of timber which were not sound. The presence of gum veins, knots and sap wood gave such faulty results, that had there been a greater number of samples those containing faults would have been discarded. He should like Professor Warren's views as to what method was used in rejecting samples which showed the presence of flaws or other defects, that should have led to their rejection. In previous tests which the speaker had made he thought they had about ten specimens for every one tested by Professor Warren. They had tested about 30,000 altogether, and having so many, and probably much more time than the Professor, they made a great number of rejections. It was then found that the results came into line more markedly, and that in the plotting of the curves they did not get results which were hard to understand. He should very much like to hear from Professor Warren an explanation as to the extraordinary differences in some of the results.

There may be other points which he might bring up later on, but he had referred to the only ones he wished to mention now. Many of the members there that night were present at the last meeting, and must have been interested in the matter put before them. He might say that the Professor had again come out against the Doctor's orders, and he thought they should fully discuss his paper while they had the opportunity of hearing his reply.

Professor Scott said that he had not the opportunity of hearing the paper read by Professor Warren, but Mr. Reeks made some remarks which went home to his heart. With regard to the rudder posts, always weak members, the stress of course is combined torsion and bending, although to a certain extent the bending can be eliminated by introducing some form of cap bearing. The Professor's experiments on torsion would, he thought, be of extreme value to naval architects. Another point was in connection with the shearing tests. One of the most difficult things in testing timber was to get a satisfactory shearing test. He had never been able to get really satisfactory tests in single shear, but the apparatus used by Professor Warren seems to come as near to perfection in that respect as possible. For his part, he thought on the whole he preferred the double shear test, and in making extensive tests for the New Zealand Government he used a device for obtaining such. The specimens were, he thought, 3 in. x 3 in., and rectangular in shape. When the load was applied to the machine the specimen failed with a distinct sharp crack. In a great number of cases the shear ran along the grain and was not exactly true with the face. The drawback of the appliance was the difficulty of removing the specimen. The cotters had to be slacked back and knocked out, and the testing machine had to make a considerable stroke before the specimen was cleared.

There was another point in connection with timber testing to which particular attention had not been given by any of them. The failure in tension was invariably a failure by shear, longitudinal shear along the fibres; he wouldn't say invariably, but in many cases, especially with the longer grained timbers. So that in reality the strength of the timber is dependent on the ratio of its cross section to its length. He tried to follow this, and up to a certain extent had increased the length of specimens until he obtained a cross section of 3 in. x $\frac{1}{2}$ in. or 1 in. timber. Testing them in the round he had used specimens of kauri or similar wood, and it had failed by longitudinal shear along the fibre. Like Mr. Julius, he was struck with the great advantages of the sand-blasting tests. They were very valuable to those who use timbers which are subject to abrasion.

Mr. Shirra said the marked difference in the behaviour of dry timber and timber saturated with moisture was brought out in the paper. The strength increased as the timber became drier. One point he would like to mention, and would like more information upon: Is the amount of contraction due to the timber drying? Teak is a very valuable timber; it does not expand or contract with moisture. The seams are always close, or nearly so, whereas with pine it is always necessary to caulk or spew off the material between the seams. In the Australian timber which is designated by the name of "Australian Teak" are there the same properties as the Indian teak? He had seen a ship's spar made of Australian teak which was full of faults. Possibly reinforced concrete could be used for railway sleepers. It is not at all improbable. It is an old dodge of bricklayers to use rusty hoop iron for bonding. By using good lime, and rusty hoop iron, it improved the bond of the brickwork very much for cantilever work without anything else but the hoop iron bonds and wood battens of $1\frac{1}{2}$ in. Such work stood for years, and only failed through moisture getting into the cracks and bursting it up. He had been trying to think of the authority, but it was an engineer in Ireland, who actually experimented with reinforced blocks of concrete, the reinforcement being wood. The question of the expansion of timber and of the effect of moisture upon it will have a lot to do with the use of wood in this respect. It may only be used to a very small extent, but there are plenty of uses for which it might be put to. For instance, concrete steps. We often see cracks which a few wood battens built into the concrete would have obviated. The same remark applies to fencing posts. If they could get any information about the expansion or contraction of Australian timbers with varying percentages of moisture, he thought it would be very useful.

THE AUTHOR'S REPLY.

The author, in reply, said he would try to remember the various points raised. First of all, Mr. Reeks referred to torsion. The paper shows some photographs of the results of torsional tests. The tests were made because of the difficulty in making satisfactory shear tests. He thought it would be very interesting to find out what the results would be in torsion, and they made a machine for the purpose. The machine was arranged so that they could apply torsional stress with any speed, and at the same time measure precisely the deformation produced by definite twists. That is to say, they could measure accurately the torsional strain produced under any twisting moment. They also had the means of drawing an automatic diagram during the course of the whole test. They made an apparatus for doing that. The results were very uniform and, he thought, very satisfactory. At all events, he was satisfied with them. Curiously enough, what is called the shear on the surface of the specimen was much higher than in any of the other shearing stresses. Torsional stress causes shearing stresses. It is a rectangular shear. It becomes deformed into a rhombus. It is a displacement. Any element of material on the surface is simply subject to shear stresses. As he pointed out in the paper, the stress at the surface is very like the stress in the extreme fibre of the beam. What they call the modulus of rupture is not the stress of the extreme fibre; within the elastic limit both torsional stress and transverse stress come out in a very satisfactory manner. One can calculate precisely the intensity of stress on the extreme fibres, provided that the stress was developed within the limit of proportionality between stresses and strains. So with torsion. When the piece is broken, it cannot be said that the shearing stress of rupture in torsion is really the shear stress of the surface. The analogy is the beam. If it were not so the torsion would be the very way to arrive at shear stresses. So it is within the elastic limit. It is an interesting result, and it certainly showed the relative shearing values of the timber, although the absolute value in the way he had calculated it is not so satisfactory. They had a special apparatus—in one of the plates it is shown very clearly—showing the exact angle between the two sections for a given twisting moment. It is elastic just like all other tests, to a certain point. Afterwards the deformation is larger, and a pure surface stress is obtained, but it cannot be compared with a direct shearing test.

In regard to shearing tests, there is not the slightest doubt that they are all most difficult to make. The average belief of all the people that have been engaged on them is that a single shear test is preferable to a double shear test. Double shear test he had always regarded as not quite as satisfactory as a single shear test. In all tests in America they never use the former method. Professors Hatt and Talbot abandoned it entirely. They used a single shear test, which at the same time is certainly open to the objections that have been raised to the single shear test be made some years ago. There is a bending moment. It cannot be eliminated but it can be reduced. He modified the process some 15 or 16 years ago, and made the pressure lip only half an inch wide; he tried to make it a quarter of an inch, but it cut into the timber so much that he could not get anything satisfactory. With a half inch wide pressure surface he was able to get the test alright without undue bending. The results came out very satisfactory as shown by the paper. There is certainly a very complex arrangement of stresses in all shearing tests, and to reduce them he rounded the piece as shown in the paper. There is no great bending moment in the test, because the pressure acts rather like a cutting face. The bending moment is practically eliminated. He did not see how any better shearing test could be made. Certainly all the tests in America are subject to bending moments, and they do not seem to make double shear tests at all. He thought they made more tests in America than anywhere else. In Germany they make single shear tests. Mr. Julius adopted Professor Johnson's methods, which he absolutely objected to, because it is not only a double shear test, but there is a bending moment as well. Professor Scott's definition of his double shear test is better, because no shearing at right angles is obtained. The material could not spread laterally. There would be a side bending moment in it, but for a double shear test it seems that it would be difficult to do anything better. We had the pressure all along the two lips. There is undoubtedly a bending moment, as Mr. Julius pointed out, but if for instance it was required to find out the behaviour of keys in compound beams, the test is an ideal one for that. It will provide the data for making compound beams of our timber, and it will show the area to make the key and all else that it is required to know. It may not be a proper shear test, all the same. In that sense it is comparable with Professor Johnson's tests which Mr. Julius described. The results with the two systems compare exactly. He did not think any other system could be devised for shearing except that in large beams of timber, of, say, 10 x 10 cross section and tested on a 10 feet span. In consequence of defects in the timber, such beams may fail frequently by horizontal shear. There you have the horizontal shearing taking place on a part of the timber which was more or less defective. That is the difficulty. There you get a pure shear of course, and there is no bending if it takes place along the neutral axis. Usually such beam tested in the machine develops very great shearing stresses, which tend to shear horizontally along the neutral axis. There is no bending moment at the neutral axis, and that test is very satisfactory. He made a lot of experiments like that, but did not publish the results of them. He got deep beams and forced them to shear along the neutral axis more or less. They very nearly always take the line at the neutral axis. The results compare very well. It was hardly worth while making a series of tests. He did not publish them, at any rate. The subject of making shearing tests applies not only to timber, but also to concrete. A large amount of attention has been paid to concrete, as can be seen from the reports of the proceedings of the International Society for testing materials. In France and Germany the same difficulties arise; they cannot get anything that they consider very satisfactory. They can only get a certain amount of satisfaction from the tests. The shearing stress of concrete is a very difficult thing to arrive at. There are wonderful divergences of the shearing strength. Speaking of reinforced concrete, he had only thought casually of using timber for reinforcing concrete, but he would not say that it is not reasonable. With regard to the expansion and contraction of the timber, if it is embedded in concrete it cannot absorb moisture, because if the concrete is watertight no moisture can get into it. In ordinary concrete there will be a very small proportion of moisture. The metal reinforcements in concrete do not rust unless there are cracks. It is fairly protected, so that the wood also ought to be alright. Then there is no doubt that hoop iron bonding is a much more important thing than it is supposed to be. It is put in brickwork and it increases the strength. Brick piers which he had tested always failed by horizontal shear. When they are built in cement mortar, if it is strong—say two parts sand to one part of good Portland cement—after two or three months the piers would carry a considerable weight. Hoop iron bonding helps in that direction. It is very interesting about Brunell building an arch with hoop iron bonding. It would certainly take the horizontal thrust. Some people seem to think that the hoop iron bond could not take any horizontal thrust, but it had half a square inch of area, and it would take much more than the horizontal thrust developed. No doubt hoop iron bonding gives brickwork an increased strength more than would be imagined. The strength depends entirely upon the strength of the mortar.

The 10 x 10 beams referred to in the tests were tested on a 10-foot span, they were broken and of course sections cut to determine the moisture. Slices of thoroughly dried timber were cut out and weighed before and after. The moisture was determined in order to see what relationship there was between the strength and moisture. A large number of specimens were obtained from every beam. The 2 x 2 inch beams were tested so that they had the same proportion in regard to depth to span as the larger beams. Twenty-four inches was the span for the 2 x 2 inch. By cutting them in the way described in the paper the pieces from the inside did not contain much more moisture than those from the outside. As already pointed out, certain timbers lost strength with the increase of moisture much more than others, but there was always a diminution in strength as the moisture contents were greater. The strength and moisture come out very well in one respect; in fact, for timber he did not think that better curves than they obtained could be procured. The curves obtained were not due to defects in the specimens, because in cutting out small pieces the doubtful-looking specimens were rejected. There was not much room for defects in a 2 x 2 inch section. There were also 4 x 4 inch beams, and these were tested on a four-foot span so as to make a geometrical proportion, the same for size. There were 2 x 2 inch, 4 x 4 inch, and 10 x 10 inch specimens, and they were not any less uniform than anything he had done in the way of timber testing. He doubted very much if greater uniformity could be obtained. These specimens were all cut from distinct trees. They were not bought in timber yards in the ordinary way, and they had the irregularities which can always be expected. Of course the co-efficient of elasticity is calculated from the deflection, and although it is known to the contrary, it appears as if there is absolutely no difference between strength and moisture. In one or two cases only is a difference noticed, and it is impossible to tell the reason why.

The President said that they had all listened with the greatest interest to the explanations and definitions given by Professor Warren. The Association was under a deep debt of gratitude to Professor Warren for allowing it to issue the results of these tests to Australia and the world generally. There was no doubt that their value was of the greatest importance, and they were distinctly honored by Professor Warren coming to them first and allowing them to issue his report to the engineering world. They ought to move a hearty vote of thanks to Professor Warren for so kindly coming to the meeting and so fully answering their questions.