brickwork would be a factor in maintaining the older construction. This being so, attention was drawn to the partial failure of so many brick stacks through want of proper reinforcement. He had noticed about two years ago the long crack which still continued to extend up the fine chimney first built for the Ultimo Power House. These cracks and the clumsy and expensive banding by which repairs were attempted, were so common that they were the rule rather than the exception. One who had experienced the oscillation of a high stack during construction, and in gusty high winds this oscillation might become periodic for a few moments resulting in a vertical fracture of the stack, extending in some cases one-third the length of the chimney, and through a vertical plane normal to the destructive wind. The use of flat bond steel in such structures was so essential that one wondered at its constant omission. The re-inforcement should consist of not less than eight straight flat bars in a course, passing from outer diameter to outer diameter tangentially past the inner diameter and within six inches of it. The resnlt was a star shaped arrangement of bars, the ends crossing each other in the centres of the wall. Such reinforcements set every 6ft. of the height of the chimney could be relied on to prevent the shearing of the chimney on its neutral axis.

The more general use of reinforced concrete was advocated, and while realizing that the applications had already been very numerous, a few others might be mentioned from his own experience.

The use of concrete steel rafts for foundation on made ground, would be found in most cases to be cheaper than sinking foundations to a depth. Sutton Chambers, in Pitt Street, built over the reclaimed part of old Sydney Cove was a successful example. The whole area under the building was covered with one single sheet or slab of concrete-steel, varying from 12in. to 17in thick, and composed of a crossed grill of $\frac{7}{8}$in. round steel bars set 6in. pitch each way and lying in a plane

2½in. distant from either surface. Thus there are four layers of steel, the section of steel per foot per layer being 1·2 inches. The earth surface was removed only sufficiently to allow for proper ventilation under the floors, and the whole surface was covered with concrete. This building had been completed about one year, and careful measurements showed that it had not settled by any amount measurable to the engineer. The cost of these foundations was one-fifth of the cost had piers been sunk, or piled foundations used. The load over the entire surface was 875lbs. per square foot. He was at the present time constructing a similar raft in the same locality, 104ft. long 40ft. wide and 12in. thick; in this case two layers of expanded steel were being used, but the cost of expanded steel per inch of metal sectional area, was much in excess of round bars, the cost per unit section at current rates at this date, being at least twice as great for expanded steel as for round rods, this great difference was however largely compensated for, in the simplicity of laying the expanded metal and the superior adhesion of the more expensive material.

In the great alluvial and basaltic areas of Australia, forming almost one-half of the whole surface, and subject to the varying changes from wet seasons to baking droughts, the use of reinforced concrete became a necessity. He had applied it with uniform success to such varied uses as concrete sheep and cattle dips, where ordinary concrete would certainly split and so cause valuable waste of antiseptic liquors.

For paving of dairy and stable floors, where previous experience showed any other method liable to fracture in the varying seasons, and more recently he had introduced the use of wire netting, pegged on the surface and covered with a thin coating of one inch of cement, as a paving for garden paths, where the absence of fracture, and the clean, and hard and pleasing surface was much to be commended.

For the construction of tanks to store water from windmills against calm days, a compound construction had been found much less expensive than wholly concrete-steel construction. These tanks should be shallow for structural reasons, up to 6 feet deep and 100 feet in diameter. A tank 60 feet in diameter was designed of sheet metal sides five feet high, $\frac{1}{8}$ thickness, fortified with a $2\frac{1}{2}$ inch x 2 inch angle iron top rim. The lower rim being bedded in concrete-steel 9 inches thick, tapering to $1\frac{3}{4}$ inches thickness at a distance of 8 feet towards the centre, the whole central area being $1\frac{3}{4}$ inches thickness of cement mortar laid upon a mesh of 3-16 inch diameter round wire rods laid 6 inch pitch. The rim plates secured with roof bolts, and insertion instead of rivetting, to enable construction with unskilled labour. The contents of this tank being 88,000 gallons. The tanks of this description were best placed on the surface, the bottom of the tank resting upon a level earth surface. As such tanks were generally required in districts where freights were expensive, weight was an important factor in cost.

Mr. Henry Shaw, said the remarkable development undergone by ferro-concrete construction, had led to a strong tendency to an adhesion to types of construction belonging to designs in the material which it had superseded. This could be recognised in almost every branch of construction to which the new method had been applied. An amusing instance of this was furnished a few months back by a well-known bimonthly, in which an Italian inventor, having invented a ferro-concrete vat, went so far as to construct each stave separately, binding the whole together with the usual wrought iron hoops.

The tendency, and the use of empirical formulæ, had largely contributed to the building of many structures with unduly large and uneconomic factors of safety, and any endeavour to furnish handy, practical working formulæ for correct designing in this material, would be welcomed by the engineer, and personally, he thanked the author most heartily for his admirable and useful contributions to the Proceedings of this Institution. Of all the professions which the coming of the "Concrete age" had benefited, none had done so, to the extent that the engineer had or was likely to. The construction of the modern building, wharf, and bridge, was becoming more and more a matter for engineering design, and it was an open secret, that the engineer with an artistic temperament was to be the man of the future.

It appeared certain, that the engineer of to-day must understand ferro-concrete construction if he intended to keep up with the procession, and the author in his paper had not only furnished a fair idea of the difficulties besetting this subject on its theoretical side, but had also given methods for the solution of its problems which, if not as handy as one might desire, were yet clear and understandable, and he was sure no one would more readily appreciate this, than the members of this institution. There were, however, difficulties which confronted the engineer in dealing with this material, other than those incidental to designing. Perhaps no class of construction required such careful selection of material or oversight in construction. Of the quality of the material little need be said here, saving perhaps to point out that, as the strength of concrete depended almost solely upon its solidity and homogenity, the ideal conditions aimed at, were to so proportion the cement, sand and stone, so that every particle of sand and stone should be coated, and all the interstices filled with cement. Much had been said with regard to the virtues of various methods of mixing. As they were aware, the usual method adopted was to mix the sand and stone separately, and afterwards add the cement. For his own part he was inclined to the opinion that a better result was obtainable by first mixing the cement and sand thoroughly, and afterwards adding the stone.

He was tempted here to say something about the grinding of the cement. It was a well-known fact that modern improvements in grinding machines had resulted in the manufacture of a much finer cement, than was possible a few years ago. The result was that a more quickly setting article had been produced, so much so, in fact, that it proved in many instances an inconvenience—the period before setting commenced not being sufficiently long for mixing and handling. In some instances gypsum was added to lengthen this period, but latterly it had been discovered that by treating the raw material with steam during the process of grinding a similar result could be obtained without the drawback of introducing an adulteration. By the steam method, it was said to be possible to pre-determine the period of setting to any reasonable degree.

Perhaps the outstanding feature which created the greatest difficulty, and called for the greatest care in handling ferro-concrete, was the fact that unlike steel, stone or timber constructions, in which, when the several members had been secured to each other with bolts, rivets, cement or what not, the structure could be put into use, ferro-concrete required a lengthy period to thoroughly consolidate. It was during this period, that due to crystallisation being in an elementary and progressive stage, the structure was peculiarly susceptible to jars and vibrations, which might set up planes of weakness, seriously affecting the subsequent stability of the whole structure. Need he say this must be guarded against, and as the evil usually arose, during construction, due to vibrations, in one part of the structure affecting adjacent finished parts, or it might be undue reflection in the mould and sets, ample strength should be provided in both the moulds and their supports. In a structure such as a wharf or building consisting of a substructure of piles, or columns, supporting a superstructure of beams, joists, and ties, it would readily be believed any local settlement at this stage might bring about serious consequences. As the cost of the timber, moulds, and sets constituted usually a considerable item in the expense of constructing, with this material it was essential for economic reasons, that as far as practicable, the parts to be moulded should be duplicates of one another, so that the same mould and set could be used again and again. In how far this could be done would generally supply the answer to the question, would ferro-concrete pay as against other forms of construction? The expenses of the sets might lead a contractor in erecting to fall into the error of removing the sets too early, an error to which was probably attributable some of the most disastrous failures in this material. The subject of sets opened out one of the most important and interesting questions in ferro-concrete construction, namely how far it could be possible to mould several parts of a structure independently, and after they had sufficiently consolidated, place them together completing the bond with new wet material. This part of the subject appeared to him to be well worthy of investigation. This mode of construction had been adopted in some cases, but as to how far such construction could be relied upon, there appeared to be no data to show. This method certainly had its attractions for the ferro-concrete engineer, to whom the building of beams and struts in almost inaccessible places was a constantly recurring difficulty. It also promised to eliminate most of the difficulties I have already indicated, which are inseparable from the usual methods of constructions.

Mr. Cook (visitor), said that this system had been adopted by the Water and Sewerage Board for the manufacture of oviform pipes. The advantage of the shape of this type was that the volume of flow had a greater velocity on account of the shape than we could get in a circular pipe. With regard to the monier work they found that these pipes were much stronger than stoneware.

Mr. F. M. Gummow said he had carefully read the author's paper and must express his thanks and appreciation for his very timely contribution to the literature on the subject. We were now at the commencement of the concrete and reinforced concrete era, and it was at such a time that it was of the utmost importance that we should not depend entirely on outside sources for information, but should look to our own scientific men to put us on a sound basis both in theory and practice. There had been many elaborate tests made abroad, but since the materials used such as sand, broken stone, cement and steel were greatly varying quantities, we must look to accurate and scientific local tests such as Professor Warren had carried out and placed at our disposal for information, for in his test the materials mentioned were readily identified and easily procurable for practical purposes in large quantities.

Regarding the formulæ developed by Professor Warren, he had not had time to apply them practically to ascertain their value over others in use, but he wished to point out that whatevor formula was used, it was also necessary to obtain sufficient practical data to design economically. Anybody scientifically and practically in touch with the subject, knew that not only the concrete mixture, workmanship and age, but the elastic behaviour of the concrete and steel as well as the proportion of the two materials to each other, had a considerable influence on the strength of the constructions, and that being so, the stresses applicable to the materials was not a constant, but a greatly varying factor. He therefore discouraged the fixing of general working stresses as the same really could only apply to certain concrete mixture and a limited range of reinforcement.

He advised making one formulæ the basis of one's researches, and not jump from one to the other as the results thus obtained varied in some instances considerably. He did not agree with Professor Warren that for square columns the best reinforcement would be angle bars at the corners, connected together on all four sides by lattice bars. These flat surfaces disconnect the concrete in a most undesirable manner, and the unequal expansion and contraction of the two materials although very slight, caused invariably cracks where the thin covering joined the bulk of the concrete. This defect applied to all concrete-steel constructions in which the reinforcement consisted of L T & H iron. From his point of view, round bars were the ideal reinforcements, taking all points into consideration, practical as well as scientific. This view was borne out by the opinion of the leading experts in concrete-steel in

Europe, and iron and steel in this form were easily obtainable, easily shaped to suit the form of the construction and the stresses therein, easily and with the greatest factor of assurance surrounded by concrete, gave the greatest possible distribution of the iron, and the least possible disconnection of the concrete, which latter points were of most vital importance in the behaviour of the construction under great differences of temperature.

He had made a close study of local (Professor Warren's test and his own), as well as foreign tests, and the data thus obtained, was his basis in calculation. To show what confidence he had in the data, he had, for some years past, in a number of cases guaranteed and tested his work to prove its accuracy, and was paid by results which he was glad to say in every case was successful.

The small pipes, referred to by Mr. Cook, manufactured by them, showed a novel application of reinforcement, inasmuch as the wire was not concentric but eccentric, necessitated by the tensile stresses appearing alternately on the inside and outside of the pipes on the vertical and horizontal axis respectively. In the larger pipes this scientific reinforcement had to be abandoned and two spirals substituted, and although adding no additional strength to the pipe when placed in position, this method was necessary to ensure safety in handling. This method of reinforcement was patented by them in the year 1898 in the Australian Colonies, and strange to say, a patent covering the same ground was only taken out in Europe 4 years later.

When visiting Europe in 1901, he made it his business to call on the leading men interested in concrete-steel, and to visit the leading works in progress, and he must say that taking everything into consideration, he found their methods were not better, and their care in execution in a great many cases less conscientious than were insisted on here. He kept his eyes open for new or improved methods or constructions, especially constructions and manufactures suitable for our Australian conditions. When his trip was completed he had to confess that there was really nothing more suitable than that already in vogue here, and so far as pipes were concerned he did not come across an article, which for cost and finish, could beat our manufacture.

He would mention a test made of two flat Tee Beams 23ft. 6in. span at Newcastle carried out by the Engineer-in-Chief for existing lines, and for which they were consulted. The working load was to be 16 tons with a factor of safety of 4, and upon testing the two beams they cracked almost simultaneously, the first crack appearing at 65 tons, and the test was considered complete with 74 tons. The Engineer-in-Chief expressed himself as very pleased with the result, not merely on account of the beams carrying the load, but because they cracked at the period, or within a close percentage of the period they were calculated to crack at.

Turning to the practical side of the question. That reinforced concrete had "caught on" was clearly demonstrated when one glanced through any engineering magazine of to-day, where one read of its successes and its failures, in fact, he was of opinion that in American it had "run riot" and must sooner or later come back to a true and rational use, and he thought he could not do better than read extracts from the "Scientific American" of recent date, which clearly set out the dangers and precautions necessary.

"A serious risk, which is none the less threatening because it is altogether unnecessary and preventable, exists in the new system of concrete-steel construction which is entering so largely into modern work. Its cheapness, its apparent simplicity of design, the ease with which its materials may be assembled, and the speed with which they can be thrown together into the finished work, have combined to render this new form of construction extremely popular."

"Let it be understood then, in the first place, that it not a simple matter to properly design the post, beams, girders, and floors of a concrete building; that is, to design them so as to secure a maximum amount of strength with a minimum amount of material. It is not nearly so simple a matter as to design a building composed of a structural steel skeleton, with tile. concrete, or masonry doors and walls."

"So true is this that there are few classes of work that come within the engineer's or architect's province, in which he is called upon to exercise such excellent judgment, and to apply so carefully the facts and principles of his profession, as in concrete steel construction. However, it is not here that the chief peril lies; not at least when reputable engineer's of standing in their profession are employed. It is when the plans are handed over to the builder with his gangs of cheap labour that the trouble begins. For unless the foremen or assistants whose duty it is to watch the actual laying and ramming of the concrete are careful and intelligent in their oversight, it is possible for the work to be so carelessly done as to greatly impair its strength, if not to make certain its ultimate collapse."

"Eternal Vigilance should be the watchword for the future if this new form of construction is to regain the reputation for combined cheapness and strength which has been so severely imperilled by the many failures of the past months."

This was a matter upon which he had always laid great stress and he might say that in order to establish confidence in reinforced concrete and place it on the same footing as structural steel work, it was necessary that the engineer who designed the work should carry it out. He was satisfied then that reinforced concretes scientifically designed, carefully carried out with best materials, best workmanship and closest supervision would become more popular daily, and although it might not be destined to take the place of steel in all sorts of constructions as optimistically predicted by some. There was no doubt of its wonderful adaptability, rapidity of construction and permanency, its field of application seemed unlimited.

On page 154 the Professor gave a formulæ for making mortar watertight. He had frequently come across information that such artificial means were being employed in America to make mortar watertight. For his part he was greatly averse to to the employment of soap and other similar substances, as oily and fatty matter had a detrimental influence on the strength and permanency of the mortar and maintained that by grading the sand and using a good proportion of cement and some lime paste and washing the surface with cement, constructions object to pressure up to a head of 100ft. could easily be made watertight,

In the Corowa Reservoir subject to a head of 60ft. they obtained watertightness without any difficulty by the judicious selection of the materials and thorough attention to workmanship.

Professor W. H. Warren in reply said there was very little he had to say, because there was little or no criticism in connection with the paper. Mr. Smail referred to plastic concrete. He had made several experiments recently, and had picked out what he considered as the most useful results. Mr. Ross gave some interesting information in connection with re-inforced brickwork. He did not think it as good as reinforced concrete, for the reason that he did not see how the same adhesion could be obtained, but it is really worth experimenting on. With regard to chimneys, he considered Mr. Shirra's remarks very interesting. A good deal has been said about the use of the concrete in connection with the piles. Mr. Walsh said that he would hardly like to risk timber piles to ships bumping against them, as it might cause fracture. Mr. Gummow might be claimed to be entirely in this class of work, and he naturally pointed to Johnstone's Creek Aqueduct. In the evidence before the Public Works Inquiry Commission, at that time most of the engineers believed that it was a bogus material. He was pleased to be able at that time to prove that it was nothing of the kind, and it would be a material un doubtedly in use in the future. That had been amply justified, when one considered the enormous number of works to-day. There was no doubt a certain amount of care was necessary, as in all work of abnormal size. In regard to making water tight cement, he agreed with Mr. Gummow that it was possible to make water tight conciete.