1 shall to-night have pleasure in describing the manufacture of Artificial Portland Cement and the machinery used for the process. Portland Cement is undoubtedly one of the most important factors in the modern building industry, as it lends itself to purposes for which no other materials could be used. Portland Cement was first made from a rock of the correct chemical composition, but nowadays most Portland Cement is made from an artificial mixture of the components. These components are Lime, Silica, Alumina and Iron Oxide, with smaller admixtures of other materials of less importance. An exact formula for the chemical composition cannot be given, and the Standard Specifications therefore give certain figures for the proportion between the components with allowances on both sides. They also state what percentages of impurities, such as Gypsum and Magnesia, can be allowed. The physical character of the raw materials is of great influence on the cement, which is the reason why the exact formula cannot be given.

An average analysis of good Portland Cement shows—

- 65 per cent. Lime
- 23.5 per cent. Silica
- 6.5 per cent. Alumina
- 2.5 per cent. Iron Oxide
- 2.5 per cent. Impurities

The strength of the cement is as a rule improved by increasing the percentage of Lime, but this can only be done to a certain extent, as the cement becomes unsound, owing to the presence of uncombined lime, if too much is added. The more Silica there is in the cement, the higher is the percentage of lime that can be allowed, and it will, therefore, be found that the best brands of cement are those high in Lime and Silica. At the same time, the sintering temperature, for such cement, rises, which limits the improving of the cement in this way. Gypsum is added in order to regulate the setting time of the cement. Without an addition of
Gypsum a first-class cement would generally set too quickly, especially when newly ground Magnesia is considered to be very detrimental to cement, and the Standard Specifications only allow for 3 per cent. admixture. The improved grinding and the preparation of the raw materials of modern times reduce the danger of the Magnesia, and in some countries the percentage allowed is raised to 5.

I shall now describe the manufacture of Artificial Portland Cement. The raw materials are limestone, or chalk where it is available, and shale or clay. These are ground and mixed together, sintered into clinker in a kiln, and ground into fine powder—the cement. Soft materials such as chalk and clay are, of course, easier to deal with than hard limestone and shale. The presence of such materials is, therefore, of great advantage to the cement industry, and a considerable number of European, especially English, factories are benefiting by using chalk. Here in Australia all cement factories are using hard limestone and shale or clay.

The quarrying of limestone for smaller factories is usually done by pneumatic drilling tools and hand labour. In such quarries the stone is blasted to a suitable size for men to handle, and the crushing takes place in crushers of a reasonable size for dealing with such stone. In big factories and in countries with expensive labour the quarry operations are somewhat differently arranged, in order to reduce the number of men. The blasting of the rock is then done on a very big scale, several hundred thousand tons may be loosened at a time, and a steam shovel digs the limestone out of the heap and loads it into trucks. It is very hard work for a steam shovel to dig in the blasted rock and the shovel must therefore be strong and powerful, but it is remarkable how well a machine of the right dimensions works, even if the wear on the dipper is considerable. The trucks are emptied into a crusher with an inlet opening sufficiently large to take pieces of about 1 cubic yard. Three types of crushers are used for the preliminary crushing—namely, Gyratory Crushers, Jaw Crushers, and Jaw Roller Crushers. The working principle of the latter might not be so well known as that of the first two. It consists of a quickly revolving roller with strong teeth and a jaw suspended by springs. The secondary crushing is done by a roller mill or hammer mill. Sometimes a feeder is used for the crusher to prevent congestion in the mill. The elevators are slow-going and of a great capacity in order to reduce the wear and tear. The preliminary crusher is here a jaw crusher, and the secondary a hammer mill in which a shaft, fitted with a number of loose hanging steel bars, revolves at high speed. These steel bars hit the stone which, when reduced to the right size, escapes through
the screen which forms a part of the housing of the machines. If the other raw material is shale, this is treated on a similar, or perhaps the same, machine, but when the material is of clay, treatment is somewhat different. The clay can be dug out of the pit by hand or by steam shovel, as described for the limestone. The dredger type of excavator, such as used in brickworks or railway cuttings, will, however, often be found more advantageous. The buckets empty the clay direct into trucks. It has the advantage, among others, that it gives a thorough mixture of the layers in the clay pit, and it can, if required, dig under water or in wet places where working would be very inconvenient. It works with a small power consumption and much more continuously than a steam shovel doing the same work. The further preparation of the raw materials—that is, grinding and mixing—can be done in two ways—namely, wet or dry. Each of the two principles has its advantages, and it is the climatic conditions and the nature of the raw materials which will decide which process to adopt. In the Australian factories there are almost equal numbers of the two types. Factories working with chalk are tied to the wet process; as chalk always contains so much water that drying would be unprofitable. Further, the chalk is so easily washed in a wash mill that a considerable saving in horse power is obtained. The quarrying cost is, of course, also much smaller for chalk. As a rule it is so arranged that the trucks are placed in the bottom of the chalk pit, and on the steep sides the men loosen the chalk with picks so that it tumbles right down into the trucks. The trucks are tipped into the wash mill by an automatic tipping device which is worked hydraulically. The two materials are washed together, and the mixture of the component parts is simply controlled by the number of trucks added. Very often a considerable number of flint pebbles are embedded in the chalk. These pebbles are left behind in the wash mill and have to be emptied out at certain intervals. One way to arrange this is to have a tunnel under the washmill and openings in the bottom through which the pebbles are discharged into trucks. The slurry produced is separated in a sieving machine, or classifier, and the coarse material is returned to the wash mill, whereas the fine stuff goes to the tube mill and from there to the slurry basin. For hard materials, such as limestone and shale, the process is not so simple. The crushed materials are extracted from the bins by feed tables, passed through a roller mill, driven by direct coupled electric motor, if such a machine were not already installed in the crushing department, and there ground and mixed. Water is also added to the mill, and the finished slurry runs out through the other trunnion of the mill to smaller tanks, where it is stirred either mechanically or pneumatically, and from there
goes to the big slurry tank. The idea is that only slurry of the correct composition can be allowed to go to the big tanks, and the variations in the slurry from the mill are balanced by emptying two or more of the basins simultaneously into the big tank. Another system of slurry mixing by air agitation in high steel or concrete tanks also gives good results, but the mechanical stirrers with simultaneous air agitation can practically never fail.

Not so long ago the grinding was done in two mills—a ball mill (or Kominor) and a tube mill. In a ball mill, steel balls fall from one step plate to another and on their way knock the stone into grains. The grains separated by sieves are collected in the casing, which surrounds the whole affair, and are conveyed to the tube mill for further grinding. The coarse particles are returned to the ball mill. The tube mill looks very much the same as the long mill, and it worked originally with flint pebbles which, by their millions of strokes, ground the material into a powder. Nowadays the pebbles are to some extent substituted by metallic grinding bodies; but huge quantities of flint pebbles are still dug out for this purpose. Many thousands of tons of pebbles, which are found in layers under water, have been dug up by an excavator of the dredger type. Inside the excavator is a belt conveyor where boys sort and collect the different sized pebbles, and, through a pipe, the water runs back. In the big Unidan Mill the ball mill and the tube mill departments are combined, which simplifies the machinery installation and the housing considerably. The requirements of strength and workmanship are greater in the larger mill, but modern structural and machine design overcomes such difficulties.

There is a great difference between the hardness of different sorts of limestone; and for every new deposit on which work is commenced it is a problem to determine the right dimensions of the grinding machinery. Some limestones are very tough and hard to crush and grind down to the size for the tube mill, whereas the fine grinding is proportionately easily done. In other cases the crusher and ball mill have easy work, whereas the final grinding is surprisingly difficult. Another difficulty sometimes arises when limestone and shale are ground dry, when the last per cent. of moisture is not driven out of the shale. A little moisture may cause the raw meal to clog and the fineness required cannot then be obtained. There are different types of stirrers. One consists of a lattice girder which is supported in the centre of the basin. In the middle of the girder is a motor which drives a shaft that, through bevelled wheels, works four stirrers, two on each side. The revolving of these stirrers makes the whole girder revolve slowly. This type, on account of its working principle, is called a sun and planet stirrer. It
works well where the raw materials, or one of them, are of a plastic nature; but for hard limestone and shale the stirring effect would be hardly sufficient. The slurry is pumped with plunger pumps with ball valves. They are built with two or three cylinders.

The Rotary Kiln is a slowly rotating cylinder resting on supports and lying with a gentle slope. The slurry, or raw meal, is fed into the upper end of the kiln and slowly approaches the fire in the lower end. The fuel is usually powdered coal, but oil and natural gas can also be used. Producer gas has not yet been used successfully, as it can hardly give a heat of sufficient intensity. The raw materials take the shape of nodules in the kiln, the carbonic acid is driven out and they are sintered at a temperature of about 1500 deg. C. to hard clinker, of sizes from small peas up to about walnut size. Rotary kilns are built in many different sizes. The biggest one the author has worked with was 250 ft. long and more than 11 ft. in diameter, and the maximum output obtained was 300 tons of clinker per day. In many places the lining will not last more than 3 or 4 weeks, but it is surprising how quickly a new lining is put in. Thirty-six hours after the kiln is stopped it can be started again. At other places the lining lasts more than half a year. It is the lime in the cement mixture that attacks the lining, which consists of Silica and Alumina, the same materials as the lime combines with when made into cement. It is therefore very important to get a crust formed in the burning zone, as this will protect the lining from further attacks. A kiln should be kept going continuously, as this crust will fall off when heated up again after having been cold, and expose the lining to a new attack. This crust can, under certain circumstances, grow to the most inconvenient size, so big that it forms a ring which closes the kiln. In earlier days much trouble arose from this before the remedy was found. The kiln had to be stopped, in some cases after only a week's run. The difficulty was overcome by adjusting the chemical composition of the raw mixture. The ring is, to a large extent, formed by the coal ash; and inferior coal with a high percentage of ash may therefore often bring difficulties. In recent years boilers are often installed for utilising the waste heat from the rotary kilns. A considerable saving in fuel is hereby obtained and the system works well. As the gases from the kiln contain a considerable quantity of dust, arrangements must be made for collecting it in the flue and under the boiler. As the gases are cooled down to a rather low temperature, a chimney of reasonable dimensions would not be able to draw the gases through the boiler, and a fan has to be installed for this purpose. The coal is usually dried in drums and ground in mills. A new
principle for simultaneous grinding and drying which has recently been adopted is that steel balls are heated and put into the mill together with the coal to be ground, thereby evaporating the water which escapes through the inlet trunnion. When the balls are cold they are taken out of the mill and heated again. When drying and grinding coal there is always a danger of spontaneous ignition. The essential point in avoiding fire is to prevent access of the air. The tube mill is undoubtedly very suitable for this purpose. The hot clinker falls from the rotary kiln into the cooler. The cooling air is forced through the cooler by means of a fan, and the hot air gained is partly used as combustion air for the kiln and partly for drying the coal. The cooler is a rotating cylinder. At the inlet end, where the heat is the greatest, it is lined with cast iron plates which are kept cool by means of air passing between them and the shell. This casing surrounds the air inlet openings.

Cement Clinker is a rather difficult material to handle in conveyors on account of its abrasive nature. Belt, and especially shaking, conveyors are much used, but the most suitable is undoubtedly a slowly moving bucket conveyor. The clinker is ground in the same type of mill as that already described for grinding raw material. The cement is bagged at the silos by pneumatic or mechanical methods. The first cost of the latter is greater, but its working expenses are less. Where cheap labour is available the pneumatic bagger is in vogue. A number of conveying machines and auxiliary machines are used in a cement factory, such as elevators, conveyors, weighing machines, sieving machines, Flencos (short centre belt drives), etc. The development of the cement industry has been very rapid, and such is also the case with the machinery used in the industry.

The position of a cement factory is determined by the proximity of the raw materials and coal, the total weight of which amounts to about double the weight of the cement. Therefore cement factories are almost always found in the country as near as possible to the deposits.

Some lantern slides from the cement works which the National Portland Cement Co. Limited is at present building on Maria Island were shown. Maria Island is one of the beautiful mountainous islands on Tasmania's east coast. There are huge deposits of limestone of different qualities from almost pure carbonate of lime to rock of a composition corresponding to natural cement rock. There is, further, a fine deposit of Kaolin clay which may be used as an adjustment to the limestone. The limestone beds are horizontal, and are evidently lifted straight up from the sea bottom where they were formed. A great number of fossils are found in the limestone.
The landing place is well sheltered from the ocean in a small bay facing towards the mainland. The chimney stack, which is built in concrete and without scaffolding, has a taper, without which a chimney of such large dimensions would look very ugly—as if the diameter were bigger at the top than at the base.

Altogether fifty-seven interesting lantern slides were exhibited by the lecturer.

DISCUSSION.

The President said he was sure it would be members' wish that he should move a very hearty vote of thanks to Mr. Tonneson for his kindness in coming and so graphically and exhaustively describing the methods of cement manufacture. He had been particularly impressed by the lecturer's masterly exposition of all the details in connection therewith, and especially with the magnificent selection of slides that had been shown. The installation Mr. Tonneson was erecting would form an important step in cement manufacture in Australia. Users of Portland cement knew, that the demand always exceeded the supply, so they welcomed every evidence of further sources of local supply.

The vote of thanks was carried by acclamation.

Mr. J. T. N. Anderson said the lecturer had shown that the methods of manufacture were continually changing. In the past the cement was stored in order to mature. He would like to know if with the new rotary mechanism it was still necessary to store the cement. At one time the system obtained of blowing steam through the cement, which was slacked before it was packed into casks for distribution.

Mr. Tonneson said it was not now necessary to store the cement. Mr. Anderson's mention of blowing steam through the cement was formerly correct, but it was not done now. The addition of gypsum took its place, and was much more reliable than the steam.

Mr. J. T. N. Anderson asked if the addition of gypsum did not increase the expansion of the cement.

Mr. Tonneson said it did not. The soundness of the cement containing gypsum was as perfect as that without gypsum.

Mr. A. L. Hargreave asked if steps were taken to prevent moisture from attacking the cement stored in silos.

Mr. Tonneson said if the silo were sound there should be no moisture inside except that contained in the cement;
unless a little sweat should occur on the walls. Sometimes the walls were coated with a solution to prevent the moisture, but in a climate like Australia there should not be any difficulty at all.

The discussion was declared closed.

VISITS.

MR. A. E. HUGHES said that a number of members had that day, at the invitation of the management of Messrs. Foy and Gibson, made an inspection of their extensive Woollen Mills in Collingwood. The mills were of great extent, and proved a revelation of the tremendous amount of work executed by the firm. The materials that were being worked up were the finest Australian wools. The Wool Disposal Board had secured to Australia all the fine Merino wools, and sold the crossbreds. Messrs. Foy and Gibson were one of the firms that worked up those fine wools. Portion of their machinery had been made by the firm themselves. The cards and looms, and the portions of the spinning machinery made by them, were equal to, and in some instances an improvement on, the imported article. The progress that had been made was clearly shown by the excellence of the product Messrs. Foy and Gibson were turning out. In the finest twills and suitings, materials were being manufactured that were the equal of anything imported from England or Scotland. The members who visited the establishment were of one opinion, that the correct thing to do was to increase the number of factories of that description. Australia had been too prone to send her raw materials to the stranger to be manufactured and then buy them back again. But Messrs. Foy and Gibson were keeping the material here and incidentally giving employment to our own people. The management spared no trouble in their effort to make the visit a success, and the Institute's thanks are specially due to Messrs. Ross and Snell for their courteous and expert guidance.

MR. J. T. N. ANDERSON reported that an enjoyable visit had been paid to the Church-street bridge now under construction. About fifty attended, and were very interested. They had the advantage of having the system of three-hinge arch method of reinforced concrete building explained by Messrs. Desbrow Annear and J. A. Laing, the architectural and engineering designers of the bridge. The work was a bold one, and the first of its kind in Australia.
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